ECO-INNOVATIONS AND COMPANIES' FINANCIAL CONSTRAINTS: A MULTILEVEL-PERSPECTIVE ANALYSIS

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Statement

I hereby declare that this thesis has not been submitted, either in the same or different form, to this or any other University for a degree.

Edgardo Sica

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SUMMARY

The present thesis investigates to what extent companies' financial constraints can hinder the development of eco-innovations, jeopardising the possibility for a sustainability transition to occur. The thesis presents a descriptive model that is assembled on the fundamentals of the well-established theoretical setting of a multi-level perspective, describing the sustainability transitions in terms of three linked levels: socio-technical landscape, socio-technical regime, and niche-innovations. More specifically, the model illustrates how financial constraints can prevent the development of eco-innovations at both regime and niche levels, effectively hindering the alignment process between the three aforementioned levels, which is necessary for a sustainability transition to occur. The theoretical model lays the foundations for the empirical investigation, which is based upon (i) an econometric analysis aimed to test the impact of financial constraints upon the eco-innovative decisions of companies at regime level and (ii) a social network analysis that investigated the extent to which financial constraints affect the readiness of technological niches where eco-innovations are developed and tested. In both cases, data were collected by means of an *ad hoc* designed questionnaire addressed to a sample of English and Italian manufacturing enterprises (for the regime level investigation) and to companies operating in the English and Italian 'hydrogen and fuel cells' and 'anaerobic digestion and biogas' niches (for the niche level investigation). Results suggest that the existence of financial constraints may reduce the probability of the manufacturing companies surveyed to engage in eco-innovative projects by up to 19% in England and 17% in Italy. At the same time, financial constraints may dangerously limit the networking activity of actors in the niches investigated, jeopardising the convergence process among knowledge, expectations, and networking that defines the development of an eco-innovative niche.

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List of most frequently used acronyms

A

ADB (Anaerobic Digestion and Biogas)

B

BA (Business Angels)

BBS (Bank-Based System)

C

CAWI (Computer Assisted Web Interviewing)

CMEs (Coordinated Market Economies)

E

EIs (Eco-Innovations)

F

FC (Financial Constraints)

FS (Financial System)

H

HFC (Hydrogen and Fuel Cells)

HoF (Hierarchy of Finance)

L

LMEs (Liberal Market Economies)

M

MBS (Market-Based System)

MLP (Multi-Level Perspective)

MRQ (Main Research Question)

O

ODS (Outsider-Dominated System)

S

SNA (Social Network Analysis)

SRQ (Subordinate Research Question)

V

VC (Venture Capital)

VoC (Varieties of Capitalism)

W

Weighted Average of Answers (WAA)

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1. INTRODUCTION

1.1 Background

In the last 50 years the need to meet increasing demands for energy, food, and water has produced a rapid and extensive alteration of ecosystems, soil degradation, loss of biodiversity, and deforestation. At the same time, the growing process of industrialisation across the world has contributed to rising greenhouse gas emissions, air and water pollution, expanding waste volumes, desertification, and chemical pollution. Given these premises, the key challenge for the coming years will be to reduce the environmental footprint of production and consumption patterns by promoting a transition towards a more resource-efficient economy (LIFE, 2009). To make this happen, a significant change in the way goods are produced and used is needed, along with a shift in the existing socio-technical structures. Although such a change is typically associated with higher economic costs, it hides large economic potential along with numerous opportunities for companies to engage in innovations that contribute towards improving environmental quality. These kinds of innovations (generally labelled in a number of different ways, e.g., 'eco-innovations', 'environmental innovations', 'green innovations', 'sustainable innovations', etc.) play a crucial role in the transition process towards a green economy, by contributing towards the successful management of the environment as well as by developing new business opportunities for companies. The term 'eco-innovation' represents an umbrella that covers innovations that are potentially developed in any economic sector and not only in the eco-industries, i.e. in industries that specifically produce goods and services to measure, prevent, limit, minimise or correct environmental damage as well as problems related to waste, noise and ecosystems. Therefore, robust and reliable statistics about the economic potential of eco-innovations are not available. Figures from the eco-industries suggest that their global market size was €1 000 billion in 2007 and €1 164 billion in 2010, with the potential to double by 2020 with the contribution of emerging countries, especially China, India, and Brazil (Rademaekers et al., 2012). In particular, the EU-27 is seen as capturing approximately one third of

the global market with roughly 3.4 million employed persons in 2012. France and Germany (followed by the UK, Italy, and the Netherlands) are the largest national eco-industry markets. The most important sectors in terms of revenue are water supply, wastewater treatment, and solid waste management.

1.2 Motivation for this research

When a certain technological paradigm is dominant, innovations happen over time along technological trajectories (Freeman and Perez, 1988; Dosi, 1982). In particular, it is possible to identify at least five major technological trajectories since the late 18th century, referred to as 'waves of innovation' (Freeman and Soete, 1997). The first occurred in the late 1700s and was based on the diffusion of textiles, waterpower, and mechanisation. The second, at the end of the 1800s, on steam power, trains, and steel. The third, in the first part of the 1900s, on electricity, chemicals, and cars. The fourth, by the middle of the twentieth century, on electronics. The fifth, in the 90s, on computers and IT. Finally, the 6th wave, that should has already started, seems to be founded upon the implementation of green technologies (Hargroves and Smith, 2005).

The diffusion of green technologies certainly represents an important step in achieving a green economy. However, an increasing body of literature (Altenburg and Pegels, 2012; Foxon et al. 2008; Geels and Schot, 2007; Geels, 2004; 2002; Elzen et al. 2004) claims that the transition towards environmental sustainability requires changes at the systemic level, which also involve social and institutional dimensions. In this framework, the analysis of eco-innovations should be carried out in their dynamic and multidimensional aspects, by taking into account their co-evolution with social and institutional systems. In contrast, despite their increasing diffusion, eco-innovations are not fully conceptualised, and the lack of a universally recognised definition in the literature makes eco-innovations a concept with unclear outlines. In particular, studies on eco-innovations seem to exhibit a general bias towards green technologies. However, eco-innovations can also include non-technological innovations (e.g. the organisational ones), which can positively affect the achievement of environmental sustainability goals. Similarly, there is no mention in the literature

about the important distinction between incremental and radical eco-innovations in the transition process towards a green economy. Moreover, literature has devoted significant efforts towards the investigation of mechanisms that foster or hinder companies to eco-innovate. However, not all the drivers and barriers of eco-innovations seem to be fully understood. In particular, despite the significance of finance influencing companies' investment decisions being widely recognised in the literature (Spielkamp and Rammel, 2009; Lazonick, 2004; O'Sullivan, 2004, Santarelli, 1995), there exists scant empirical research that investigates the potential financial constraints faced by eco-innovating companies. Therefore, the present thesis aims to increase knowledge about eco-innovations by investigating the extent to which financial constraints of companies hinder their eco-innovative decisions. In particular, eco-innovations are analysed in their multidimensional nature, by taking into account their co-evolution with the existing systems and structures. To do this, the thesis develops some hypotheses, which are then tested empirically.

1.3 Theoretical model

The thesis presents a descriptive model that is assembled from the fundamentals of the well-established theoretical setting of the evolutionary theory, in an attempt to capture the contribution of eco-innovations to the transition from the current (unsustainable) regime to a green economy where eco-innovations become the market standard and environmental issues are fully integrated into all economic processes. In this context, the model tries to identify the extent to which financial constraints can hinder the eco-innovative behaviour of companies and, consequently, the transition process towards a more sustainable regime. More specifically, the model is grounded in the framework of the multi-level perspective (Geels, 2002; Rip and Kemp, 1998), which describes the sociotechnical transitions in terms of three linked levels: socio-technical landscape (i.e. the macro level), socio-technical regime (i.e. the meso level), and niche-innovations (i.e. the micro level). According to the model, niche-innovations struggle against the existing regime and therefore require changes in the socio-technical regime (e.g. in consumer practices, public policies, etc.) in order to sufficiently propagate. When the sociotechnical

landscape exerts a destabilisation pressure on the existing regime (and eventually on the niche), niche-innovations have the opportunity to emerge and compete with the existing regime, and eventually enter the mainstream markets. In this framework, the thesis assesses the role played by financial constraints upon the process of sustainability transitions by integrating the financial dimension into the original model. In particular, the model describes how financial constraints can prevent the development of eco-innovations, both at regime and niche levels, and jeopardising the alignment process between the three aforementioned levels (i.e. landscape, regime, and niche), which is necessary for a sustainability transition to occur.

1.4 Research questions

The overall aim of the present thesis is to generate knowledge regarding the impact that financial constraints of eco-innovative companies can have upon the process of a sociotechnical transition towards a more sustainable regime. To this end, it introduces a financial economics perspective within the literature about eco-innovations, exploring the nexus between financial constraints and eco-innovative decisions of companies in the framework of the multi-level perspective and presents empirical evidence to test theoretical assertions and implications. Indeed, the problem of how to finance an investment project (i.e. whether to employ internal or external sources of funding) represents a critical decision for companies. However, the imperfect substitutability between internal and external financing makes enterprises financially constrained in the occurrence of a shortage of internal funds. Therefore, the existence of financial constraints can prevent companies from funding a desired eco-innovative project. The Main Research Question (MRQ) that this thesis attempts to answer is therefore the following:

> *MRQ: Is the process of a sustainability transition hindered by the existence of financial constraints to eco-innovative companies?*

Since the above MRQ is rather broad, two Subordinate Research Questions (SRQs) will be addressed to operationalise the overall objective of the thesis.

The first SRQ assesses the nexus between financial constraints and incremental eco-innovations at regime level by investigating the extent to which the existence of financial constraints hinder regime level companies from engaging in eco-innovating projects, thus jeopardising the possibility of creating 'windows of opportunity' that would allow radical eco-innovations at niche level to enter the dominant (unsustainable) regime:

> *SRQ1: What is the impact of financial constraints upon the decision of regime level companies to engage in eco-innovative projects?*

The second SRQ relates to the role of financial constraints as a barrier to the development of radical eco-innovations at niche level, by assessing the extent to which financial constraints interfere with the readiness of eco-innovative niches and consequently hinder the possibility for the niche to enter and replace the dominant regime:

> *SRQ2: Do financial constraints affect the readiness of eco-innovative niches?*

In order to answer the above MRQ and SRQs, the present thesis takes into account different strands of literature and, in particular; the evolutionary analysis of sociotechnical transitions within the multi-level perspective, the literature on companies' financial decisions and capital instruments, the literature on the determinants of financial constraints, the neoclassical approach to the problem of environmental externalities, as well as to the asymmetric information in the capital markets. Furthermore, the thesis marginally takes into account the 'varieties of capitalism' approach.

1.5 Research methodology

The empirical analysis carried out in the thesis was based upon the implementation of a survey that employed behavioural and attitudinal measures collected by means of *ad hoc* designed questionnaires to investigate to what

extent financial constraints can affect the process of a sustainability transition. Questionnaires were administrated by means of the 'Computer Assisted Web Interviewing' technique: companies were firstly informed telephonically about the research purposes of the thesis and then received a web-link by email, thus having the possibility to fill the questionnaire online. According to the theoretical model developed in the thesis, the empirical investigation was split into two parts. The first focused upon the sociotechnical regime by analysing the impact of financial constraints upon the implementation of incremental eco-innovations. The second explored the extent to which financial constraints affect the development of radical eco-innovations at niche level, hindering the possibility for a niche to enter the dominant regime.

More specifically, the regime-level analysis carried out a comparative study between English and Italian manufacturing industries. As will be discussed in Chapter 2, eco-innovations are not limited to eco-industries, since they are an integral part of the innovative effort of companies across different industries. From this perspective, English and Italian manufacturing industries exhibit a large percentage of innovative enterprises as well as high levels of environmental protection expenditure, making manufacturing companies a potentially significant matter of analysis. Moreover, England and Italy are characterised by contrasting financial system architectures that literature recognises to be among the most significant determinants of financial constraints. The thesis develops and employs a novel approach for recognising the eco-innovative enterprises. Starting from a sample of English and Italian manufacturing companies drawn from already existent databases, the regime-level questionnaire tried to identify which enterprises from the sample group eco-innovated and what they did in making an eco-innovation, before proceeding with more specific questions including those on financial constraints. The distinctive characteristic of this approach is that companies surveyed were not pre-supplied with a definition of eco-innovation, but, instead, were asked to offer their own definition of what an eco-innovation is. This allowed understanding companies' viewpoints on eco-innovations and avoided forcing them to adopt a definition that they may not understand or agree with. The data collected made it possible to draw a descriptive picture about the characteristics

of the eco-innovative companies surveyed. Furthermore, the use of a probit model allowed econometrically defining the impact of FC upon the probability of companies to engage in eco-innovative projects.

Similar to the regime-level investigation, the niche-level analysis focused upon a comparative study between English and Italian eco-innovative companies. In this case, enterprises surveyed were those operating in two different eco-innovative niches, i.e. the hydrogen and fuel cells niche and the anaerobic digestion and biogas niche. This allowed simultaneously taking into account the most relevant domains, which can actively contribute to the transition towards a more sustainable regime, i.e. energy, food, and mobility (see Geels, 2013). Hydrogen and fuel cells play a significant role in, both, new energy and transport systems, while anaerobic digestion and biogas enables producing energy starting from a number of different feedstocks, including agricultural residues and food waste, and can be used as an alternative renewable fuel for transport. Moreover, the two niches are considerably interlinked with each other, hydrogen being easily produced also from biomass and biogas. Data collected were used to draw a descriptive analysis about the niche companies surveyed as well as to assess the impact of financial constraints upon the niche readiness. To this end, the research method employed was a social network analysis that allowed investigating the effect of financial constraints upon the three key niche mechanisms that define the development of a technological niche, namely, expectations, learning process, and network formation.

1.6 Structure of the thesis

The thesis consists of seven chapters (including the present introduction and the last conclusive chapter), which can be grouped into five main sections (Table 1).

Table 1 Organisation of the thesis

SECTIONS	SECTION I Introduction and conceptualisation of eco-innovations	SECTION II Further relevant literature	SECTION III Theoretical model	SECTION IV Empirical analysis	SECTION V Conclusions
TOPICS	▪ Introduction, motivation of the research, and research questions ▪ Definition and types of eco-innovations ▪ A comparison between neoclassical and the evolutionary approaches	Literature review on: ▪ Drivers and barriers of eco-innovations ▪ Companies' financial decisions ▪ Determinants of financial constraints (specifically on different financial systems)	▪ Integration of literature from sections I and II ▪ Derivation of the theoretical model ▪ Derivation of the research hypotheses	▪ Methodology ▪ Hypotheses testing ▪ Presentation of results achieved	▪ Summary ▪ Implications ▪ Further lines of research
CHAPTERS	1, 2	3	4	5, 6	7

Although sections' lengths vary, all five parts contribute equally to the general aim of the thesis. In particular:

- After briefly describing the motivation of the research, the theoretical model, research questions, methodology, and structure of the thesis (in Chapter 1), **section I** deals with the definition of eco-innovations and with a critical review of the role that they play within the neoclassical and the evolutionary approaches (Chapter 2). This section argues that eco-innovations should be defined by taking into account their environmental performance (i.e. whether they cause a net environmental improvement) rather than their environmental motivation (i.e. the intention of companies to implement innovations beneficial to the environment). Moreover, it provides important definitions such as radical/incremental eco-innovations and technological/non-technological eco-innovations. Finally, the section highlights how the analysis of eco-innovations can find space in the framework of different approaches, ranging from the more traditional neoclassical literature on innovations to the new evolutionary studies on the techno-paradigm shifts, showing critical strengths and weaknesses of both approaches.
- **Section II** (Chapter 3) deals with the review of other relevant literature. This section can be virtually split into three parts. The first reviews the existing theoretical and empirical knowledge about the main drivers and barriers of eco-innovations, showing the existence of a gap in the literature, i.e. the lack of former investigations about the role of financial constraints to foster or hinder the eco-innovative behaviour of enterprises. The second reviews literature on companies' financial decisions and capital instruments, discussing the problem of asymmetric information in capital market and the theory of hierarchy of finance. This part explores the role of environmental reputation as a possible way for eco-innovating companies to limit the asymmetric information toward prospective investors due to the lower perceived compliance costs and liabilities. Finally, the third part discusses the determinants of financial constraints specifically within different financial systems. Following an evolutionary perspective, this part argues that the financial system represents a complex system with characteristics that depend upon the different combinations of the system components.

- **Section III** (Chapter 4) deals with the theoretical model employed in the thesis and shortly presented in section 1.3. The model integrates the literature discussed in Section I in a comprehensive framework that lays the foundations for the empirical investigation carried out in the thesis.
- **Section IV** (Chapters 5 and 6) deals with the empirical investigation. In particular, Chapter 5 explains in detail the research methodology shortly discussed in section 1.5. The chapter can be split in two parts. The first deals with the regime-level analysis by discussing the context of the analysis, the econometric model adopted to empirically test some research hypotheses, the reason for using the questionnaire for collecting data, the technique adopted for the sample selection and the questionnaire administration, and the questionnaire design. The second part concentrates upon the niche-level investigation, by presenting the characteristics of the niches selected, the research method (i.e. the social network analysis) employed to analyse data, the technique adopted for the questionnaire administration, and the questionnaire design. Chapter 6 reports the results achieved from the empirical investigation. Following the structure of Chapter 5, it is split in two parts that discuss the findings obtained, respectively, from the regime-level and the niche-level investigations. In both cases, the chapter reports on the analysis of responses collected and some figures about the companies surveyed before presenting the results achieved from the econometric investigation (for the regime-level enterprises) and the social network analysis (for the niche-level companies).
- Finally, **Section V** (Chapter 7) summarises the results achieved from the empirical investigation, discussing their implications and further lines of research.

1.7 Shortcomings

The present thesis investigates the extent to which financial constraints hinder the eco-innovative decisions of companies. The thesis combines existing knowledge from different bodies of literature to develop a theoretical model and to formulate research hypotheses that are then empirically validated. The conceptualisation of eco-innovations in Chapter 2 allows carrying out an in-

depth analysis of this kind of innovation that proceeds with the analysis of financially related problems of eco-innovating companies. However, the analysis presents some shortcomings that will be discussed in detail in section 7.3. For instance, data was collected by means of a questionnaire based upon behavioural and attitudinal measures. In particular, financial constraints were measured by employing a direct indicator based on the company's perception of barriers faced when seeking to finance its eco-innovative activities. Moreover, the empirical investigation is limited to a comparative study between English and Italian companies and therefore does not take into account the impact that other financial system configurations can exert upon the companies' financial constraints. Finally, the regime-level analysis is limited to a sample of enterprises drawn from the manufacturing industry, while the niche-level investigation takes into account only two niches in each of the two countries. From this point of view, further cases should be investigated in order to achieve additional empirical evidence.

2. DEFINING ECO-INNOVATIONS: CHARACTERISTICS, TYPOLOGIES, AND SOCIO-ECONOMIC APPROACHES

2.1 Introduction

Economic theory considers innovation a process aimed to improve the competitiveness of companies, with their potential to contribute to economic growth. Indeed, innovative competences of companies represent a key driver of profitability and business success for enterprises other than a way to increase the employment opportunities of a country (Stosic et al., 2016). A definition of innovation commonly referred to is that of Schumpeter, according to which innovations represent 'the commercial or industrial application of something new – a new product, process or method of production; a new market or source of supply; a new form of commercial, business or financial organisation' (Schumpeter, 1912 / 1934). Innovations are thus first-time applications of newly acquired know-how, methods, or products, new to the market or to the business itself, and can include non-technological aspects, such as changes in a company's organisation or in product design. In this framework, the on-going debate about the importance of sustainable pathways of economic development has moved the interest of many economists toward a particular type of innovation that is able to preserve environmental resources (Braungardt et al., 2016; Scarpellini et al., 2016; Klewitz and Hansen, 2014). Such innovations, generally labelled in the literature as 'eco-innovations' (Hojnik and Ruzzier, 2016; De Medeiros et al., 2014; Horbach et al., 2012; Carrillo-Hermosilla et al., 2010; Horbach, 2008; MEI, 2008; Hellström, 2007; Bernauer, 2006; Beise and Rennings, 2005; Rennings and Zwick, 2002; FIU, 1998)[1] can be considered as innovations inclined toward environmental preservation. Thus, whereas the definition of innovation is somewhat neutral concerning the content of change,

[1] Or, alternatively, as 'environmental innovations', 'green innovations', 'less-polluting innovations', 'sustainable innovations', etc. At regards, Angelo et al. (2012) and Schiederig et al. (2012) have reviewed the terms used so far in the literature to label eco-innovations, finding out that the term 'environmental innovation' has been employed in the majority of reviewed papers (65%), although, since 2005, the notion 'eco-innovation' became increasingly used in scientific publications. Anyway, it is worth noting that such 'labels' are not perfect synonyms. For instance, 'sustainable' should refer to the social and economic dimensions of innovations other than to the environmental one; 'eco' to the ecological dimension, etc.

the concept of ‘Eco-Innovations’ (henceforth EIs) emphasises the direction and content of progress. In this framework, the distinctive characteristic of EIs is to reduce the environmental burden and to deal with specific problematic areas, such as greenhouse effect, loss of biodiversity, resource and land use, etc. (Bossle et al., 2016). However, despite the importance of EIs in the economic debate on environmental sustainability, the way they may contribute to sustainable pathways of development seems to still be unclear. In particular, the analysis of EIs has recently found space in the framework of different economic approaches, ranging from the more traditional neoclassical studies on innovations to the new evolutionary literature on the techno-economic paradigm shifts. Although both approaches acknowledge the significant role played by EIs in fostering environmental sustainability, they dramatically disagree on the way EIs may drive economies toward sustainability. Based on this background, the present chapter aims at contributing to the existing literature by exploring and contextualising roles and functions of EIs for sustainability in the framework of the neoclassical and the evolutionary schools of thought. The chapter is organised as follows. Section 2.2 defines EIs by focusing on their environmental performance rather than on their environmental motivation, as well as by considering the existence of non-technological *versus* technological EIs and of incremental *versus* radical EIs. Sections 2.3 and 2.4 regard the analysis of EIs in the framework of the neoclassical and the evolutionary perspectives. In particular, Section 2.3 explores EIs according to the neoclassical approach, by focusing on the technological progress necessary to achieve environmentally sustainable pathways and on the regulatory framework to drive the development and diffusion of EIs. Section 2.4 investigates EIs according to the evolutionary perspective, by analysing their role in achieving sociotechnical transitions and in greening the innovation systems. Finally, Section 2.5 makes a general discussion by comparing the two theoretical approaches and underlying the implications for the present thesis.

2.2 Conceptualising Eco-Innovations

The concept of ‘EIs’ can be considered as a response developed to address environmental impacts (Erenfeldt, 2008). Such a response includes changes in

technologies and ways of thinking in order to improve the environmental performance of products, services, and the way they are created. Literature has so far proposed many different definitions of EIs although they can be broadly classified into two main groups. The first group considers EIs as a sub-class of innovations that improve both the economic and the environmental performance of society (Huppes et al., 2008). For instance, Lee and Min (2015), Triguero et al. (2013), Dangelico and Pujari (2010) and James (1997) considered EIs as the generation of new products and processes that provide customer and business value but significantly decrease environmental impacts. Similarly, Kemp and Pearson (2008) and Kemp et al. (2001) defined EIs as the whole of new or modified products, processes, techniques, and systems that avoid or reduce environmental damage and that allow the same use value at a lower environmental cost. Within this group, it is possible to include also definitions that focus on some specific characteristics of EIs, as in the case of Norberg-Bohm (1999) who argued that EIs are innovations that reduce environmental impacts through waste minimisation. The second group seems to broaden the concept of EIs, which are not considered just as a sub-class of innovations, but rather, in more general terms, as the introduction of environmental dimensions in economic strategies (Blättel-Mink, 1998). For instance, Ghisetti and Pontoni, 2015; Hellström, 2007; Rennings (2000), and Klemmer et al. (1999) argued that, along with process, product, and organisational changes in the management of companies, EIs include also changes at social and political levels as well as changes in environmentally counter-productive regulations and legislature, consumer behaviour, and lifestyle in general. Similarly, in the 'Innovation Impacts of Environmental Policy Instruments' project (FIU, 1998), EIs are defined as all measures undertaken by relevant actors (companies, politicians, unions, associations, churches, private households) which (i) develop new ideas, behaviour, products and processes, apply or introduce them, and (ii) contribute to a reduction of environmental burdens or to ecologically specified sustainability targets. Also Huber (2005, 2004) has defined EIs as techno-organisational, social, and institutional changes leading to improvement in the quality of the environment.

Although the above discussion highlights the lack of a distinct and universally recognised definition of EIs in the literature, at least two key-elements seem to characterise EIs (see also Díaz-García et al., 2015):

1. The importance of their *environmental performance* rather than the *environmental motivation* of the innovator.
2. The existence of 'technological', 'non-technological', 'incremental', and 'radical' EIs.

2.2.1 Companies' strategies, environmental motivation, and environmental performance

As will be discussed in Chapter 3 in more detail, EIs may depend on the corporate strategic attitude of companies, i.e. on the extent to which company's managers react to stakeholders' pressures, market characteristics, and innovation potentials. Specifically, EIs can result from three different environmental company strategies:

- A follower strategy, when a company just complies with legal and regulation requirements;
- A market-oriented strategy, when the environment is subordinate to the business strategy of a company and single environmental actions are the consequence of specific market and competitive choices;
- An environment-oriented strategy, when the environment is seen as a key factor for companies to succeed, becoming thus integrated into the corporate strategy.

However, many authors (e.g. Ryszko, 2016; Przychodzen and Przychodzen, 2015; Noci and Verganti, 1999; Van Wassenhov and Corbett, 1991) argue that companies can no longer rely on defensive or re-active environmental strategies, but they should incorporate decisions concerning the introduction of EIs into the process of strategy formation.[2] Despite this, the *environmental*

[2] On these grounds, the emergence of the Corporate Social Responsibility (CSR) – i.e. the obligation for companies to manage their operations in such a way to maintain environmental protection and to promote social responsibility in their business operations and in their interaction with stakeholders on a voluntary basis - represents the managerial answer of companies to the global interests for sustainable development by integrating the environmental and social dimensions in their strategy (EC, 2001). As will be discussed in the section 3.3.2.5, a

motivation of innovating companies, i.e. their intentions behind implementing EIs, is neither a necessary nor a sufficient condition for classifying the output of their innovative effort as an 'EI'. However, to correctly define EIs, it is crucial to take into account the *environmental performance* of innovations, by considering whether they cause a 'net environmental improvement', i.e. whether the environmental situation (in general or in certain aspects) has been preserved or even improved thanks to the innovation or not (Kemp and Arundel, 1998). The reason why *environmental motivation* is not necessary to define EIs is because companies can achieve environmental preservation without pursuing any environmental strategy. Although the eco-innovative process should generally be founded upon an *environmental motivation*, other situations may exist where environmental preservation is produced indirectly as an inseparable element of the innovation generated, making some innovations that are beneficial to the environment not readily recognisable as EIs (Machiba, 2010; Rennings and Zwick, 2002). An example might be the increased fuel efficiency of cars arising from the incremental improvement of the motor: although the prime motivation for such an innovation is most likely performance or price considerations, the effects on the environment may in any case be positive. Thus, EIs may not occur exclusively in the 'eco-industries' (which specifically produce goods and services that measure, prevent, limit, minimise, and correct environmental damage)[3], but may occur in any productive sector, since they can be an integral part of the innovative efforts of companies across industries (Urbaniec, 2015; OECD/Eurostat 1999). The reason why *environmental motivation* is insufficient

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large strand of literature has proved that CSR initiatives can lead to reputational advantages, improvements in investors' trust in the company, more efficient use of resources, and new market opportunities (Guestner et al., 2011).

[3] Eco-industries refer generally to those sectors within which the main, or a substantial part of, activities are undertaken with the primary purpose of the development of technologies and the production of goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and ecosystems (Rademaekers, 2012). These include:

- *Pollution management activities*, such as air pollution control; wastewater management; solid waste management; remediation and clean-up of soil and water; noise and vibration abatement; environmental monitoring, analysis and assessment;
- *Cleaner technologies and products*, which improve, reduce or eliminate environmental impact of technologies, processes and products (e.g. fuel-cell vehicles);
- *Resource management activities*, which focus on resource efficiency and development of new environmentally preferable resources (e.g. energy saving, renewable energy plant) (Ekins, 2010).

for defining ‘EIs’ is because intentional EIs can also produce negative environmental effects, such as in the case of crops for biogas that can lead to the destruction of forestland, releasing considerable quantities of greenhouses gases. Thus, more significant than the aim of innovations, is whether there are positive and recognised environmental effects related to their use.

The environmental performance of innovations can be assessed by referring to the use of relevant alternatives, for instance the technology used by a company or the normal technology in a sector (see Chassagnon and Haned, 2015). Thus, some possible evaluation criteria are: the reduction in the material intensity of goods or services, the reduced dispersion of toxic materials, the improved recyclability, the maximum use of renewable resources, the greater durability of products, the increased service intensity of goods and services, etc. However, such assessment requires extensive knowledge and understanding of the innovation and its contextual relationships, since environmental consequences may occur because of an unexpected interaction with other factors.

Consider, for example, the provision of wireless internet connections in trains: although such adjustment consumes additional energy, thus leading to a decline in environmental performance, the overall environmental impact could more than offset such negative effect if the new facility attracts travellers who otherwise would travel by air or cars. EIs may, to a large extent, be systemic and complex in that they involve many areas of knowledge and many different industrial sectors. Two studies, one for the European Commission and one for the OECD, elaborated that the percentage of innovative companies that *do not* implement EIs either intentionally or unintentionally is only between 20%-30% and that more than half of all technological innovations in general have been estimated to have beneficial effects on the environment (Kanerva et al., 2009). Another OECD study (2008) shows that many companies take environmental considerations into account even when environmental improvements are not the main objective of their research and innovation efforts, and that they often do not see any difference between ‘general innovations’ and ‘EIs’.

2.2.2 Technological and non-technological EIs

In general terms, innovations can be classified in different ways according to their objective, drivers, intensity, etc. (Norman and Verganti, 2014). In the case of EIs, the most relevant classification concerns the distinction between 'technological' and 'non-technological' EIs and between 'incremental' and 'radical' EIs.

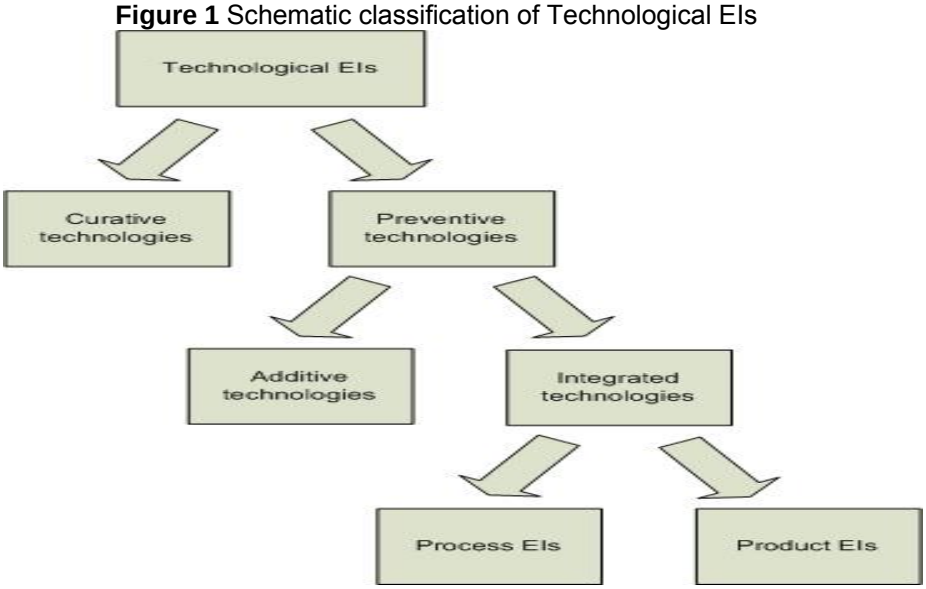
According to the literature (Rashid et al., 2015; Chappin, 2008; Kemp et al., 2001; Rennings, 2000) technological EIs consist of process and product innovations while non-technological EIs consist of organisational innovations. This classification broadly reflects the definition of innovation reported in the Oslo Manual, according to which an innovation is '*the implementation of a new or significantly improved product - good or service -, or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations*' (Oslo Manual, 2005: 10). It is worth noting that the classification between product, process, and organisational EIs can be indistinct: for instance, product EIs in machinery in one company may represent process EIs for another company; moreover, although organisational EIs are a specific type of EI, they can be complementary to the implementation of technological EIs, etc.

Technological EIs

Include both *curative* and *preventive* measures. The first aims at repairing environmental damages (*ex-post*) while the second at avoiding them (*ex-ante*). *Preventive* technologies may be distinguished in *additive* and *integrated* (see

Figure 1).

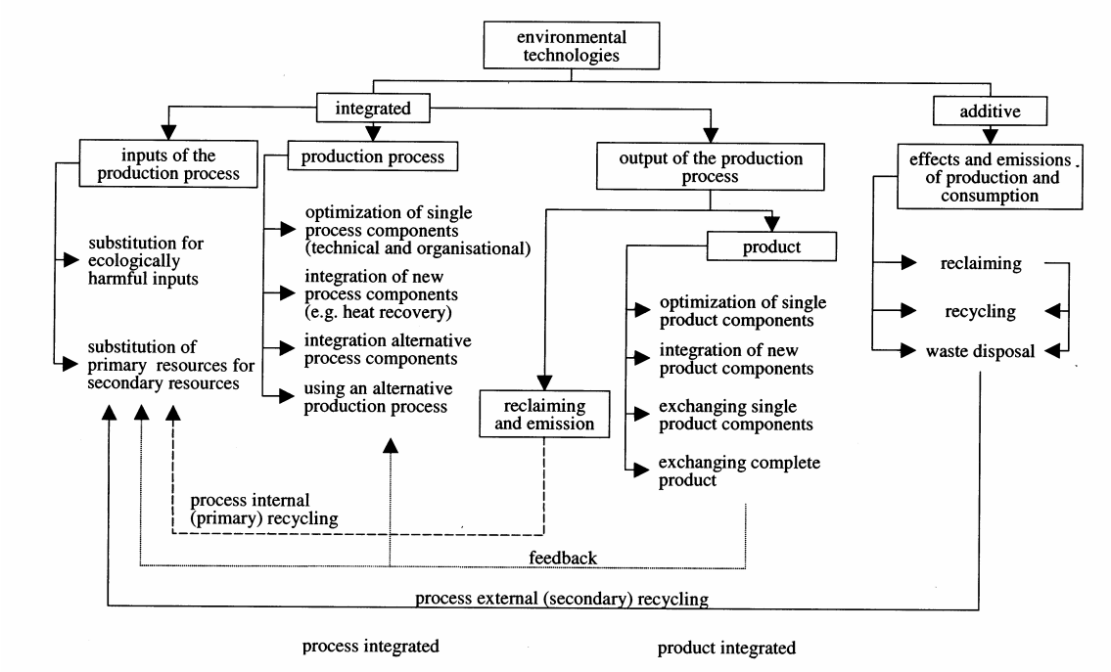
Figure 1 Schematic classification of Technological EIs



(**Source:** own elaboration based on the main literature)

Additive measures are end-of-pipe technologies that occur after a production process has taken place and before the stream is disposed of or delivered. They are used to remove already formed contaminants from a stream of air, water, waste, product, or similar. *Integrated* measures can be split into process and product technologies. They prevent environmental damages during the production process and at the product level (Figure 2).

Figure 2 Types of technological EIs



(**Source:** Rennings, 2000)

Process innovation concerns changes in the way inputs in a production process are transformed into outputs (Chappin, 2008). Product innovations comprise changes in the composition, *design*, operation, quality, or function(s) of goods and services: the way these factors are combined determines the level of *eco-efficiency* of a product (Jang et al., 2015; OECD, 2011; Rubik, 2001).[4] Examples of traditional end-of-pipe technologies are air purification technologies (e.g. filters for industrial facilities, filters for indoor rooms), waste treatment technologies regarding collection and transport, and material recovery facilities, environmental biotechnology (i.e. the development, use and regulation of biological systems to remediate contaminated environments). Examples of integrated measures are environmental monitoring technologies that help the ascertainment, observation and surveillance of natural processes (e.g. satellite

[4] It is worth explaining the linkages between product EIs and two related but different concepts, i.e. *eco-design* and *eco-efficiency* (see Halila, 2007: 11-14, for a complete review on this topic).

- *Eco-design* focuses on how to integrate environmental considerations in the development of products, by addressing all their environmental impacts without compromising other criteria like function, quality, cost and appearance.
- *Eco-efficiency* measures the value of a product or service against its environmental impact and aims at obtaining more value with less environmental consequences. It represents a comprehensive notion that can be applied to various levels of analysis, such as product, company, sector, region, or the entire economy.

On this ground, although product EIs should provide the consumers with the function they require in a more eco-efficient way, they are not necessarily based on the re-design of an existing product (see Brezet, 1997, for a classification of technological EIs based on different levels of eco-efficiency improvements).

observation, measurement of fine particulates in inner cities), technologies for reuse or recycling, technologies for saving resources or to conserve both materials and energy when producing and operating products (e.g. the minimisation of friction in movable engine parts to save fuel), regenerative, fuelless energy (e.g. photovoltaic, wind, hydro, tidal, wave, solar, and, geothermal energy), replacing hazardous chemicals by more benign low-impact substances, biofeedstocks partially replacing fossils as a raw material, new ultra-light, ultra-strong materials, which reduce energy and volumes compared to conventional materials, and nanotechnology and micromachines, which cause less environmental impact compared to larger conventional machines and chemical production (see Huber, 2008, p. 361). Despite the fact that downstream end-of-pipe technologies still represent a large amount of technological EIs (and, according to some authors, they will continue to be necessary anyway to control specific emissions in the near future, see, for instance, Frondel et al., 2004), from the 1970s to the present day policy makers, companies, and public opinion have exhibited a growing interest towards the preventive rather than the curative measures, which they increasingly consider insufficient and too expensive to solve massive environmental problems (Durán-Romero and Urraca-Ruiz, 2015).[5]

Non-technological EIs

Non-technological EIs are essentially organisational innovations that comprise all measures aiming at incorporating environmental perspectives into companies' operations and at developing an environmentally respectful awareness and new priorities in policies and practices. They include the introduction of organisational methods and management systems for dealing

[5] It is possible to identify four main stages that have characterised the general development and diffusion of technological EIs since the early 1970s to the present day (see Markusson, 2001):
(i) early 1970s: technological EIs were primarily motivated by energy savings given the recent energy shock,
(i) mid 1970s - mid 1980s: end-of-pipe technologies were used as a passive response to the environmental policy developed by many western governments,
(i) second half of the 1980s: technological EIs were usually timed with systems renovation as a defensive medium-term approach,
(i) end 1980s - present: technological EIs have been included in the corporate strategy and are aimed at acquiring a competitive advantage.

with environmental issues in production and products. Examples of non-technological EIs are: pollution prevention schemes aimed at preventing pollution through input substitution, more efficient operation of processes, and small changes to production plants (avoiding or stopping leakages); environmental management and auditing systems that involve measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste (e.g. the EU Eco-Management and Audit Scheme - EMAS - and the ISO 14000 series); chain management, i.e. cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave) (see MEI, 2008: 10).

A number of authors (Ghisetti and Pontoni, 2015; Hellström, 2007; Hertwich and Katzmayr, 2003; Ottoman, 1998; Hemmelskamp, 1997; Fussler and James, 1996) have broadened the group of non-technological EIs to also include:

- 'Social EIs', i.e. changes in lifestyle and consumer behaviour as a consequence of increased awareness about environmental problems. They comprise mobility (public transport use instead of private cars, car sharing), nutrition (non-packed, seasonal and organic food consumption), housing (energy saving for heating, cooling and warm water, eco-houses), clothing (wash-machine use only with a full load, clothes recycling), services (eco-leases) and generally all those measures that make consumption more sustainable
- 'Institutional EIs', i.e. the creation of new regimes of environmental governance, such as local network agencies, international environmental organisations, etc.

However, according to the Schumpeterian definition of innovation, both 'social' and 'institutional' EIs should not be considered as a type of innovation, since they are not company-centred innovations (refer also to the Oslo Manual, 2005). However, their importance for sustainable pathways of development is nowadays largely recognised in the evolutionary analysis of EIs. Indeed, as will be discussed in section 2.4.1, the transition towards a more sustainable regime can happen only because of the co-evolution of technical and social elements: in this framework, technological EIs co-exist and co-evolve with organisational EIs as well as with changes at the social and institutional levels.

The other relevant classification can be made according to the intensity of innovation between 'incremental' and 'radical' EIs. Incremental EIs take place more or less continuously in companies, although at dissimilar rates in different industries and over time periods (Freeman et al., 1982). They occur mainly as the result of inventions and improvements suggested by customers and suppliers and/or by workers directly engaged in the production process. Moreover, incremental EIs are generally, but not always, curative measures that repair environmental damages instead of preventing them. By contrast, radical EIs are discontinuous events that are unevenly distributed over sectors and time and are the result of deliberate research and development processes in companies (Freeman et al., 1982). Radical EIs are generally preventive measures which are initially small and localised, unless they emerge in a new industry.

Technological, non-technological, incremental and radical EIs as a whole play a significant role toward creating more sustainable pathways of development. However, the way they contribute to sustainability changes according to the economic approach considered, in particular whether neoclassical or evolutionary.

2.3 The neoclassical analysis of EIs

The neoclassical analysis of EIs - developed within the framework of 'Environmental Economics' - is centred on two issues. The first is the capacity of EIs to contribute towards sustainable development pathways through *technological progress*, i.e. by offsetting the negative effects of the exhaustion of natural resources and pollution generation. This can happen through (i) the substitution of scarce natural resources with manufactured capital, and (ii) improvement in factor productivity. The second is in regards to the importance of the regulatory framework as a driver of EIs. The next two sections explore the above two issues separately.

2.3.1 EIs and technological progress

From the neoclassical perspective, EIs play a crucial role in achieving targets of environmental sustainability. However, the neoclassical analysis seems to be focused essentially upon technological rather than on non-technological EIs, without taking into account any possible distinction between incremental and radical innovations. Within the Ricardian relative scarcity framework, neoclassical economists are optimistic that technological EIs can reduce the potential constraint on economic growth imposed by the resource scarcity (Venkatachalam, 2007). From a methodological point of view, neoclassicists extend the models of growth and capital accumulation to include natural capital. For example, Solow (1974) shows that it is possible to include the environment in growth models without altering their tractability (see also Cai 2007; Sica, 2007). Similarly, the 'individual rationality' based macromodels developed by Hotelling (1931) and Hartwick (1977) explore the sustainability of resource use. Such models conclude that a non-diminishing per capita consumption path can be maintained indefinitely insofar as *technical progress* is able to (i) substitute scarce natural resources with manufactured capital, and to (ii) improve the factor productivity. Indeed, neoclassicists are confident that *technology*, as a tool, can enable the capacity of the economy-environment system to satisfy human needs (Common and Stagl, 2005). In this framework, EIs contribute positively to environmentally sustainable pathways of development by executing tasks (i) and (ii) above, providing employment increases as well (Crespi et al., 2016).

The importance of technological progress to achieve targets of environmental sustainability can be easily identified by observing the *'Environmental Kuznets Curve'* (EKC); the well-known inverted-U shaped (empirical) relationship between the level of economic activity and air pollution emissions in advanced industrial nations (Grossmann and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1993). The EKC is founded upon the idea that, as income grows, the level of pollution in a country rises since the main purpose of the first stages of development is to increase production, with a consequent use of great volumes of natural resources and a general depletion of the environment

(Dasgupta et al., 2002). However, in the following phases of growth, the level of pollution declines after reaching a 'turning point': as a wealthy nation can then afford to spend more on Research and Development (R&D), innovations and technological progress, which occur concurrently with economic growth, with the obsolete technologies being replaced by the cleaner ones (Dinda, 2004; Komen et al., 1997). In this process, technological EIs therefore play a crucial role in achieving environmental sustainability targets, by encouraging the efficient use of natural resources, so that a given amount of goods may be produced by employing a reduced quantity of natural resources or energy (Weina et al., 2016).

Moreover, when individuals enjoy greater incomes, they become more inclined to care for the quality of natural resources and to show an increased willingness to invest in the environment in which they live. This pushes companies to be more eco-innovative (Mazzanti and Zoboli, 2007; Bousquet and Favard, 2000; Stagl, 1999). It is worth noting that not all agree with this analysis. From a global perspective, the EKC in one country can result from the shifting of polluting industries towards the poorest countries, which represent thus 'pollution havens' (Kearsley and Riddel, 2010; Kellenberg, 2009; Cole and Fredriksson, 2009; Cole, 2004). In other words, rich countries may simply export their polluting industries to jurisdictions with less stringent environmental regulations where pressures for a clean environment are secondary to growth.

Similarly, the '*Ecological modernisation*' (EM) approach, which has an underlying political economy founded upon neoclassical environmental economics, argues that any environmental problem may be solved through further advancements of technology and industrialisation, without any need to stop the process of industrialisation to deal with ecological crises (Foster, 1992; O'Connor, 1991). Indeed, supporters of EM believe in 'super-industrialisation' (i.e. the transformation of industrial production based on the development of advanced technologies) as a means to address environmental problems (Fisher and Freudenburg, 2001; Andersen and Massa, 2000). In this framework, the diffusion of systematic EIs must be encouraged to reduce the environmental burden (Jang et al., 2015). In particular, the nexus between EIs and the environment founds upon the key-concepts of:

- *Efficiency*: since policies useful to promote EIs may simultaneously result in both economic and environmental benefits (Murphy and Gouldson, 2000): EIs may reduce the consumption of raw materials and the emissions of a number of pollutants and, at the same time, they may create competitive products;
- *Precaution*: since damages to the environment should be avoided in advance, it is necessary to to keep economic development separate from environmentally dangerous production processes (Boehmer-Christiansen, 1994). In this framework, EIs may contribute positively to the 'precautionary principle' (*Vorsorgeprinzip*, in German) since *precaution* means developing innovations that reduce environmental burdens by taking time and effort to consider all possible alternatives and to gather deeper information in the eco-innovative process (Stirling, 2016, Barry, 2005; Andersen and Massa, 2000).
- *Social market*: since through emission standards, environmental taxes, and other preventive rather than curative or end-of-pipe regulatory mechanisms, regulation may drive the process of industrial innovation with environmental and economic gains realised as a result (Murphy and Gouldson, 2000). In this framework, governments should provide financial support to EIs while the private sector should develop, test, and market them. In other words, there is a preference for market-based solutions: the governments set the environmental targets and the market decides how to achieve them.[6]

Overall, neoclassicists therefore seem to believe that technological EIs represent the main tool to achieve environmentally sustainable pathways of development. This view has been deeply criticised by an opposing line of thought that assumes that technological progress cannot avoid fundamental energy and resource constraints (Barnett and Morse, 1963). In this framework,

[6] It is worth noting that both in the EKC and in the EM approaches, EIs are developed essentially by the private sector. The main difference between the two viewpoints is that, in the EKC, EIs are developed within an economic framework of complete governmental *laissez faire*, since the environment does not need any specific attention. However, in the EM approach, EIs are generally developed by the market thanks to the supportive action of governments that have the task of implementing policies to deal with environmental problems into the growth-oriented and globalized economy.

ecological economists argue that, along with the more efficient use of resources, technological EIs also involve new processes and products that cause additional pressure on the environment (Shmelev, 2012; Daly and Farley, 2011). Moreover, the final effects of technological change cannot be foreseeable, since an increase in efficiency in the use of natural resources may stimulate the demand for them, thus reducing or even deleting the mitigating effects of the efficiency increase (Roca and Padilla, 2007).

2.3.2 EIs and regulatory framework

The neoclassical approach to EIs is also based upon the study of the regulatory framework necessary for their implementation. From this perspective, the analysis of EIs spans *'environmental economics*' and '*innovation economics*'. On the one hand, *environmental economics* focuses on the public good nature of the environment and on the 'double externality problem' of EIs, by developing methods and strategies to assess environmental policy instruments aimed at correcting the market failure that arises from it. The starting point of the discussion is that EIs can combine a benefit for the company or user along with an environmental benefit depending on the characteristics of the innovation (Hemmelskamp, 1997).[7] The combination of these externalities, is likely to result in substantial under-investments in eco-innovative projects and this justifies the importance of the regulatory framework as a driver of EIs (Marin et al., 2015). In other words, environmental policy measures are necessary to 'internalise' externalities using different policy instruments. On the other hand, *innovation economics* analyses the elements influencing the implementation of EIs, by giving prominence to environmental policies as a key-factor for companies' eco-innovativeness. Recognising the importance of the regulatory framework, neoclassicists emphasise methods and strategies to assess environmental policy instruments in an effort to correct the market failure arising

[7] For instance, 'organic' food creates benefits for both the user (taste, health) and the environment (less pesticides) compared to conventional products; other EIs (such as electricity from renewable energy) most often lack additional private benefits compared to the use of fossil or nuclear energy.

from the double externality problem. Although such aspects are thoroughly analysed in Chapter 3, it is worth stressing here the argument proposed by Porter and van der Linde (1995 a, b) who suggest that, by pushing enterprises to eco-innovate, environmental regulation may improve the natural environment, on the one hand, and the companies' competitiveness, on the other ('Porter Hypothesis' - PH). This means that well-designed environmental policies may lead to a win-win situation where both the *social welfare* and the *private net benefits* of companies increase (Ghisetti et al., 2015). The reason why stringent environmental regulation may raise *social welfare* is well recognised among the neoclassical economists: since the marginal social cost is higher than the marginal private cost in the presence of negative externalities, and environmental regulation may correct such market failure.

However, how environmental regulation can increase *private welfare* is less obvious. In this regard, the PH argues that environmental regulations can drive companies to implement EIs that may partially or even completely, offset the static private adaption costs. Consequently, stringent environmental policies may boost the competitiveness of regulated companies through improved technical efficiency: '*properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them*' (Porter and van der Linde, 1995b: 98). In other words, regulations drive the eco-innovative behaviour of companies that, in turn, contribute towards increasing their profits (Mohr and Saha, 2008; Brunnermeier and Cohen, 2003). More specifically, Porter and van der Linde argue that companies may not have realised all of the possible profitable opportunities due to their imperfect management systems. Thus, well-designed legislation may inform companies about their drawbacks, pushing them to consider opportunity costs (Rave et al., 2011; Horbach, 2006; Cerin, 2006). Moreover, environmental regulations can represent an opportunity for firms to gain a competitive first mover advantage (Chassagnon and Haned, 2015). It is worth noting that the win-win situation proposed by Porter and van der Linde may not always be the case. Some authors (Hottenrott and Rexhäuser, 2013; Roediger-Schluga, 2003; Gray and Shadbegian, 1998) argue that environmental regulation can instigate a crowding out effect since companies are forced to devote considerable

financial and human efforts to satisfying the given requirements and consequently they lack resources for other innovative projects at least in the short-term. In some cases, companies can also adopt expensive end-of-pipe technological EIs with the aim to (i) increasing the pollution control costs towards their current competitors, which are thus crowded out from the industry, and to (ii) create entry barriers to their potential competitors (Keohane et al, 1998).

2.4 The evolutionary analysis of EIs

The evolutionary approach extends the analysis of EIs by including social and institutional aspects along with technology. Evolutionists adopt an inductive approach founded upon observations of the complex reality that changes over time (Faucheux et al., 1996): their holistic approach makes them more interested in the analysis of transitions and learning processes than in equilibrium states, and assumes bounded rationality of eco-innovative companies rather than optimisation criteria. Thus, whereas neoclassical theory deals with marginal conditions and economic equilibrium, evolutionists focus more on conflict aspects of economic processes and explain changes in terms of systems' capacities to adapt to crises. By extending the analysis beyond the purely economic aspects, within the view of the evolutionary framework, EIs are developed and diffused not only based on the extent of their characteristics (cost, quality, etc.), but also on the grounds of their compatibility with existing systems and structures (Kemp, 1993). Along with the technological intensity of the company's operations and the nature of the knowledge they involve, evolutionists stress the relevance of coordination between actors and institutional frameworks that support it (Galliano and Nadel, 2015). Therefore, whereas neoclassicists tend to investigate specific aspects of EIs (double externality problem, environmental regulation, efficiency, etc.), the evolutionary approach explores EIs in their dynamic and multi-dimensional nature, by considering them as dependent upon the interactions of technical, sociological, and economic systems. In other words, the evolutionists analyse EIs in the broader context of their co-evolution with social and institutional systems, by

placing emphasis on the necessity of their re-organisation within a broader ‘green paradigm’ (Rennings, 1998). Indeed, according to this perspective, environmental preservation may still be possible through ‘incremental’ EIs, but larger jumps towards environmental sustainability may only be possible through systemic EIs, which involve new technological artefacts, markets, user practices, regulations and infrastructures.

2.4.1 EIs and ‘Sociotechnical Regimes’

An interesting approach to analyse EIs in the framework of the evolutionary studies reflects upon the so-called ‘Sociotechnical Regimes’ (Geels, 2004; 2002). Such issue stems from the ‘technological regime’ concept (Nelson and Winter, 1982), which represents shared cognitive routines in an engineering community that help to explain patterned development along technological trajectories (Geels and Schot, 2007). Since scientists, policy makers, users, special-interest groups, etc., contribute to patterning of technological development, evolutionists have expanded the concept of ‘technological regime’ in order to also include a broader community of social groups. From this perspective, changes are based on mechanisms of co-evolution of society and technology (Kern, 2012). The sociotechnical regime offers useful insights into the reasons why some EIs may fail, despite promising better environmental performance. The basic idea is that EIs are introduced into systems developed for older technologies and this may result in some resistance and inertia regarding their adoption because of the already existing routines, tasks, qualifications, user-producer relationships, etc. (Murphy and Gouldson, 2000). Thus, many promising technological EIs are not adopted, since the existing system is ‘locked in’ on many dimensions (economic, social, cultural, infrastructural, regulatory, etc.), as are the consequent user practices, regulations and infrastructure (Elzen et al., 2004) that would have to change along with new technology.

The existing sociotechnical regime receives destabilisation pressures from the sociotechnical landscape, which is the wider context where activities carried out

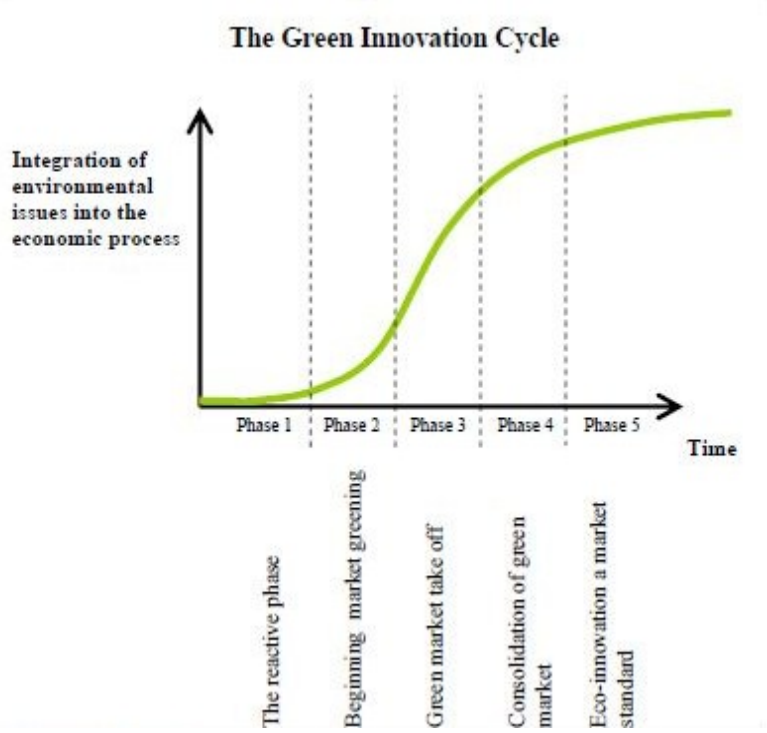
by the regime are situated. The landscape is an external structure or context for interactions of actors and includes elements at a macroeconomic level, such as material infrastructure, political culture and coalitions, social values, worldviews and paradigms, demography, natural environment, etc. (Geels, 2004). Consequently, technological changes can take place only within particular trajectories: due to the pressures of the selection environment, a certain technology becomes a dominant 'technological paradigm' that excludes other evolutionary options (Fallde and Eklund, 2015). In this framework, radical EIs driven by new scientific insights may emerge essentially through technological niches or niche markets that act as 'incubation rooms', where initially unstable sociotechnical configurations are protected against mainstream market selection (Geels and Schot, 2007). Even if niches perform poorly in more conventional terms, such as price, convenience, speed, etc., in such protected spaces, EIs are given the opportunity to be appreciated, evaluated, and to mature through gradual experimentation and learning of producers, users, researchers, and others, as was the case with organic foods (Smith, 2006). As a result of destabilisation pressures on the existing regime from the sociotechnical landscape, EIs in the niches have the opportunity to emerge and compete with the existing regime, going into the mainstream markets: this implies that EIs need to be fostered through strategic policies of niche management.

2.4.2 EIs and Green Innovation Systems

Innovation systems represent all the elements and their interrelations that exist in the production, diffusion, and use of new and economically useful knowledge (Freeman, 1995; Lundvall, 1992). Within the evolutionary perspective, they provide an analytical framework to analyse how some technologies give rise to specific technological trajectories. EIs can therefore be viewed as the market standard for 'green innovation systems', i.e. innovation systems where environmental issues are fully integrated into the economic process (Foxon et al, 2008; Jacobsson and Bergek, 2004). Green innovation systems are networks of institutions that create, import, modify, and diffuse EIs (Altenburg and Pegels, 2012). Following such a perspective, EIs are placed within the

wider context of the knowledge economy and are analysed from a dynamic perspective (Rand Europe, 2000). The greening of innovation systems requires addressing the environmental inconsistencies between different segments of the system, such as policy and research areas, technical and market standards, financial institutes, etc. Foxon and Andersen (2009) identify five different phases of this process, each one is characterised by significantly different levels of development and diffusion of EIs (Figure 3).

Figure 3 The process of greening of the innovation system



(**Source**: Foxon and Andersen, 2009: 19)

The first phase is the demand of environmental regulations for EIs. The second and the third are the beginning and the launch of green markets, respectively. The fourth is the consolidation of green economy. The fifth and final phase is the wide diffusion of EIs as a market standard for the economy. In particular, the rationale for environmental policies in the first phase addresses the necessity for governments to correct for multiple market failures: in this framework, reaching efficient market solutions (or even 'second best' solutions) is unreasonable and thus the role of public intervention becomes the identification and the possible solution of 'system failures' in infrastructure and investment provision, along with transition and lock-in failures (Foxon, 2007; Grubb and

Ulph, 2002; Edquist, 2001; Smith, 2000).[8] Foxon and Andersen (2009) believe that the first phase started in the 1950s and they considered the environment as a burden to business. The second phase started at the beginning of the 1990s, when integrated product policies and clean technologies support companies began to appear in the market. The critical shift towards the green market take off (third phase) is currently happening and is still accelerating: it is surprisingly rapid compared to the long first phase and the rather slow second one. Nothing can be said about when (or if) the transition to the fourth and fifth phases will take place. Table 2 reports the main co-evolutionary processes taking place within an innovation system in the transition towards a green techno-economic paradigm, showing the most important implications in terms of EIs. While moving along the above co-evolutionary stages, green competitiveness becomes increasingly important and influences the selection of suppliers, customers, learning partners, employees, and financial institutes, to name a few. Once the Green Innovation System is achieved, EIs become the natural innovations that are then routinized and mainstreamed. It is worth noting that the greening of the innovation system also depends on the interaction between environmental and technology policies, other than on the interaction of the different actors in the innovation process, going beyond the purely technical EIs (Hübner et al. 2001).

[8] In many cases, multiple system failures can lead to policy prescriptions similar to those suggested by the neoclassicists, such as the use of economic instruments to internalise negative environmental externalities. The key-difference between the two approaches is that the innovation system perspective does not presume that public policy interventions can recreate economic efficiency: Markets are based on a set of legal and institutional rules and the task of policy makers is to design such rules so that they are not excessively costly to companies and individuals.

Table 2 Co-evolutionary processes towards a green innovation system

		PHASES				
		1st (Reaction)	**2nd (Green Market beginning)**	**3rd (Green market taking off)**	**4th (Consolidation)**	**5th (Market Standard)**
ACTORS	**Innovation/Technologies**	Wasteful economic paradigm	Resource-efficient trajectory emerging	EIs rising in many business areas	EIs competitive	Resource-efficient technoeconomic paradigm
	Institutions (Regulatory Body, Government)	Clean up role	Market supporting		Seeding EIs	Greening is 'in the air'
	Companies	Obstructive and reactive strategies to regulation	Early eco-innovative companies	Environmental proactive companies	Widespread proactive environmental strategies,	Routine environmental strategies, High environmental standard profile
	Sectoral Innovation Systems	Uneven greening Sector specific	Polluting industries greening	Development of sectoral environmental strategies	Widespread proactive environmental strategies,	All sectors high environmental profile
	Knowledge Institutions	Attention to environmental issues only in traditional environmental research areas		Rising interest into environmental areas	Widespread green search and education	Routine green search and education
	Consumers	Reactive,	Few green users	Rising green consumerism	Widespread green demand	Routine consideration of green demand
	National/Regional/Global Innovation System	No green market	High friction to early EIs	Medium friction to EIs	Strong green knowledge base	Well-functioning green markets

(**Source**: own elaboration based on Foxon and Andersen, 2009)

2.5 Discussion and implications

Although the importance of innovations for the environmental preservation is well recognised in the literature, the concept of EIs remains vague and has unclear outlines. The lack of distinct definition of EIs along with the numerous ways EIs are referred to in the literature (environmental innovations, green innovations, less-polluting innovations, sustainable innovations, etc.) contributes to generating further confusion. However, to correctly define EIs it is necessary to take into account: (i) the environmental performance of innovations (i.e. whether they cause a net environmental improvement or not) rather than the environmental motivation of the innovators (i.e. the eventual intention of companies to implement an innovation that is beneficial to the environment), and (ii) the existence of 'technological' along with 'non-technological' EIs.

Keeping in mind that this thesis highlights how the analysis of EIs can find space in the framework of different approaches, ranging from the more traditional neoclassical literature on innovations to the new evolutionary studies on the techno-paradigm shifts. Certainly, the most important contribution of the neoclassical approach is the analysis of the specific characteristics of EIs, in terms of cost, quality, etc. However, one of the great merits of the evolutionary approach has been the introduction of social and institutional aspects in the analysis of EIs. Indeed, whereas neoclassicists put companies at the core of the eco-innovative effort, evolutionists also take into account the possible existence of environmentally friendly changes at both social and institutional levels, thus avoiding the risk of 'technological bias' in their analysis. It is interesting to observe that both approaches devote a large space to examining the reasons why some promising EIs with better environmental and economic performance are not developed or adopted. According to the neoclassicists, this is due to the market failure that arises from the double externality problem of EIs, focusing on the concepts of partial equilibrium and marginal conditions as typical of the neoclassical framework. However, the evolutionists believe that some EIs have not further developed because they are embedded in an inappropriate existing complex system. Regulation is another overlapping topic in the analysis of EIs: indeed both neoclassicists and evolutionists provide a rationale for the

necessity of eco-innovative policies. For neoclassicists, regulation represents probably the most important driver of EIs, given the market failure arising from the double externality problem, which implies suboptimal EI investments in the enterprises. In particular, governments and regulatory bodies may correct such market failure through specific and well-designed environmental policies and/or through innovation support activities, i.e. by providing eco-innovating companies with access to finance and by delivering them business support services. In both cases, the neoclassicists devote significant efforts towards analysing the effectiveness of regulations. Furthermore, evolutionists provide a rationale for regulation in terms of management of the socio-economic elements of a complex system and specifically in terms of niche management and system failures. When the existing regime receives destabilising pressure from the sociotechnical landscape, regulation is necessary to ensure that emerging EIs in specific niches have the possibility to be evaluated and appreciated. Similarly, system failures in innovation systems justify the intervention of some form of regulation in the market economy by providing public support for infrastructure, by helping companies to cope with technological changes, by generating incentives for EIs, and by overcoming barriers created by the prevalence of incumbent technology.

This literature review provides the foundation for subsequent analysis and, in particular, for the theoretical model that will be introduced in Chapter 4. Indeed, to answer the research questions discussed in Chapter 1 and deal with the knowledge gaps, the present thesis will investigate the financial constraints of eco-innovating companies by integrating the neoclassical and the evolutionary approaches. Specifically, the thesis accepts that technological (and organisational) EIs are a promising step towards attaining environmental sustainability targets, but disagrees with the neoclassical idea that technology itself is capable of accomplishing environmentally sustainable pathways of development. Indeed, despite a general focus on the company-level view, this thesis acknowledges the importance of co-evolutionary changes at both social and institutional levels that are required to achieve environmental sustainability. In particular, it recognises that a number of internal and external barriers to companies, including companies' financial constraints, can hinder some

promising EIs to succeed, thus contributing to them becoming locked-in within the existing regime. The acknowledgment of the importance of social and institutional changes along with technological ones should assist avoiding the possible risk of 'technological bias' in the thesis. Furthermore, the thesis recognises the role of regulatory action in driving the eco-innovativeness of companies. Well-designed policies may contribute towards limiting the barriers that hinder some EIs to succeed, thus increasing both the social welfare and the private benefits of companies. Therefore, the general view accepted in this thesis is that environmental sustainability may only be possible through a systemic shift, which involves technological and organisational EIs as well as changes at the social and institutional levels. However, within the broader context of such a multi-level perspective, the thesis exploits a neoclassical approach to investigate the specific elements that drive companies' eco-innovativeness or that contribute to hinder EIs from succeeding.

3. FURTHER LITERATURE REVIEW

3.1 Introduction

The present chapter lays a further foundation for the theoretical model that will be presented in Chapter 4. To achieve this, additional relevant literature is reviewed that is useful for answering the research questions proposed in Chapter 1. In particular, the first part of the chapter (section 3.2) deals with the existing theoretical and empirical knowledge about the main drivers and barriers of companies' eco-innovativeness. This section will show the existence of a gap in the literature on EIs, i.e. the lack of former investigations to address the role of finance to foster or hinder the eco-innovative decisions of companies. The second part of the chapter (sections 3.3 and 3.4) discusses finance theory and the corresponding empirical findings, by focusing on two main bodies of literature. The first includes literature on capital structure and the theory of hierarchy of finance (section 3.3). The second focuses upon the determinants of companies' financial constraints, with particular reference to the role of different financial systems (section 3.4).

3.2 Drivers and barriers of EIs: existing theoretical and empirical knowledge

The main incentive for innovation activities in companies is driven by the possibility of achieving higher market shares and more profit with respect to their competitors (Horbach, 2005). In turn, this is affected by a number of internal company characteristics (e.g. company size, cost-savings associated with the implementation of innovations, etc.) and external company drivers (e.g. market characteristics and competitiveness level, etc.). However, in the case of EIs, further eco-related external drivers should be taken into account, such as the type and effectiveness of environmental policy adopted, as well as the environmental consciousness of consumers and their related preference for environmentally friendly goods and services (Oosterhuis and Kuik, 2008). This section shortly reviews all the above aspects.[9]

3.2.1 Environmental policy

Environmental policy represents the entire regulatory, economic, and communicative instruments that policy makers can employ to drive EIs. It plays a central role in spurring the diffusion of EI and in creating lead markets for eco-innovators, provided that it should be investigated within the framework of its interactions with other EI drivers (Costantini et al., 2015; Ghisetti et al., 2015; Schmidt et al., 2012; Rehfeld et al., 2007; Popp, 2006; Becker and Englmann, 2005; Del Río, 2005; Türpitz, 2004; Newell et al., 2002; Montalvo, 2002; Similä, 2002; Pickman, 1998; Hemmelskamp, 1997; Kemp, 1997). Both neoclassicists and innovation-system supporters provide a rationale for the importance of environmental policies for eco-innovativeness.

In the neoclassical framework, some form of policy intervention, for instance as public support for R&D, is most often necessary to foster innovations, since new knowledge can be copied with the consequence that innovators cannot

[9] For a complete overview of the emerging literature on the drivers of EIs, see Hojnik and Ruzzier (2016), Bossle et al. (2016), Del Río et al. (2016).

appropriate the full benefits of their investment in knowledge creation. In other words, companies may lack the incentives necessary to undertake socially efficient levels of innovative activity. In economic terms, this means that the social returns to innovation exceed the private returns, leading to innovation activating a public good, i.e. non-rival and non-excludable (Arrow, 1962). Specifically, innovations are non-excludable, since the access of other users cannot be denied once they have been supplied. They are non-rival since their use by one agent does not reduce the amount available to others. Consequently, innovations may be undersupplied, because non-paying free riders cannot be excluded from the market. In order to correct for such market failure, it is therefore necessary to create some form of policy intervention (Foxon, 2007). In the case of EIs, the existence of a further externality (i.e. the environmental benefits arising from EIs) provides a rationale for the necessity of the environmental policy to drive the eco-innovative efforts of companies (see section 2.3.2). For the neoclassicists, therefore, EIs are more policy-driven and less market-driven than other types of innovation (Del Río et al., 2015; Horbach et al. 2012). However, the potential of environmental policy as a driver of EIs depends largely upon the characteristics of environmental goods.

Consider, for example, the differences between water use and air emissions. With water emissions, it is more likely that companies autonomously adopt saving strategies whether or not environmental regulations are set. With air emissions, this is less likely, given the public good nature of emissions, which are more difficult to internalize. In other words, the eco-innovativeness of companies is associated with rents that they can appropriate at least partially. On these grounds, EIs can be seen as private goods, or at least as the private part of a quasi-public good, characterised by other pure public features. For this reason, some authors (Mazzanti and Zoboli, 2007; Ziegler and Rennings, 2004) argue that the role of environmental policy emerges as a correction mechanism for externalities not already tackled by the endogenous technological dynamics developed by companies and industries, which are driven by demand, cost, product value added, and other market-based motivations. Consequently, the importance of environmental policy, as a driver of EIs, depends upon the characteristics of environmental externality: a correlation between private and

public elements of EIs may reduce such an outcome, favouring the eco-innovative efforts of companies even in the absence of any policy intervention.

From the broader perspective of the innovation systems literature, the legitimate justification and scope for policy intervention in this field founds upon the necessity for governments to correct for multiple market failures (Borrás and Edquist, 2013). In this framework, the role of governments to reach efficient market solutions (or even to find 'second best' solutions) is unreasonable and the rationale for public intervention becomes the identification and the possible solution of 'system failures' (Grubb and Ulph, 2002; Edquist, 2001). Such system failures can be classified into four main areas (Smith, 2000):

1. *Failures in infrastructure provision and investment*, since physical and science-technology infrastructures for innovations are unlikely to be sufficiently provided by private investors because of their large scale and extensive testing operations;
2. *Transition failures*, since existing companies may experience numerous and broad difficulties to respond to technological changes;
3. *Lock-in failures*, since the adoption of new technologies may be hindered by existing technologies, which are 'locked in' because of path dependence and because they are closely linked to their social and economic environment. Thus new technologies must compete not only with the existing dominant technology, but also challenge the overall technological and institutional system in which it is embedded;
4. *Institutional failures*, since the set of public and private institutions, regulatory and policy system creates a framework of opportunities and barriers to innovations.

In this framework, policy makers may provide public support for infrastructure, help companies to cope with technological changes, generate incentives for new technologies or technological systems or to overcome barriers created by the prevalence of incumbent technology, monitor and assess the performance of regulatory and policy systems. The system failures can lead to adopting similar policy prescriptions to solve market failures in the neoclassical viewpoint, such as the use of environmental policy to foster EIs. The key-difference between the two approaches is that the innovation system perspective does not

presume that public policy interventions can recreate economic efficiency: markets are based on a set of legal and institutional rules and the task of policy makers is to design such rules so that they are not excessively costly for companies.

3.2.1.1 The impact of different environmental policy instruments on EIs

The environmental policy instruments (regulatory, economic, and communicative) can drive companies to eco-innovate differently (Jang et al., 2015; Kemp, 2000). Regulatory or 'command and control' instruments affect the environmental performance of companies by establishing and enforcing laws and regulations that prescribe technologies, objectives, and standards which polluters must comply with. More specifically, they can specify methods and equipment that companies must use to meet the target set (technology-based instruments) or establish the overall target of companies giving them some discretion regarding how that standard is met (performance-based instruments). Although regulatory instruments represent a powerful tool for spurring EIs, especially when companies expect that those EIs will become the basis for a future standard, they give little thought to the development of more systemic EIs, since the choice to comply with, or to face penalties through judicial and/or administrative procedures is left to the polluter. Consequently, they provide small incentives to companies looking for 'greener' solutions (i.e. additional measures to improve environmental consequences) once the standards or obligations are met. Indeed, the most common responses to regulation instruments are generally incremental EIs, such as the diffusion of end-of-pipe solutions (see Kemp, 1998).

Economic or 'market based' instruments (charges, fees, taxes, tradable permits, deposit-refund schemes, subsidies) employ price mechanisms and financial incentives to encourage companies to eco-innovate. Since polluting companies reduce their emission as long as the marginal cost of abatement is lower than the charge rate, economic instruments always offer incentives to eco-innovate because of the possibility of abatement and charge payment savings. These measures may help to achieve static efficiency (or 'cheaper now'), since

companies that find it relatively cheap to undertake reductions do more than companies that find it more expensive. Moreover they contribute to pursuing dynamic efficiency (or 'cheaper in the future'), since placing a price on effluents creates a permanent incentive to generate new processes or equipment, to develop new product designs, to create new abatement methods, and to reconfigure existing production lines to reduce the outflow of the targeted pollutants (Markusson, 2001). Thus, in contrast with regulatory measures, economic instruments provide an incessant incentive to invest in integrated EIs rather than end-of-pipe solutions (Johnstone, 2005; Requate, 2005; Anderson et al., 2001).

Finally, communicative instruments (education, training, social pressure, negotiation, and other forms of 'moral' persuasion) aim at internalising environmental awareness and responsibility into companies through the application of interactive communication rather than one-way imperatives. When such instruments are not employed in conjunction with regulatory or economic instruments they seem to perform as drivers of EIs (Markusson, 2001; Kemp, 2000, Hemmelskamp, 1997). It is worth noting that, along with driving companies to eco-innovate, environmental policy can also be a barrier to EIs, since it may imply extra-costs for companies with the consequent reduction of money available for eco-innovative investments. Moreover, environmental policy can limit the innovation options because it imposes time pressure and bureaucracy boundaries on companies, limiting them from innovating freely. Finally, uncertainty about regulation may push companies' managers to develop risk-avoiding behaviour, resulting in less EIs (Chappin, 2008; Hall, 2003; Marcus et al., 2002; Gunningham and Sinclair, 1998). Empirical studies that investigate the eco-innovative effects of different environmental policy instruments are quite dispersed in the literature (for a survey see Pereira Sánchez, and Vence Deza, 2015, and Kemp and Pontoglio, 2011).

Table 3 summarises some of the main works on the topic. It shows the lack of general consensus about the most suitable instrument to drive EIs.

Table 3 Ex post assessment about the effects of different environmental policy on EIs: some empirical studies

AUTHORS	FOCUS	MAIN FINDINGS
Ashford et al. (1985)	Ten regulatory cases in the US after 1970	Regulatory instruments (standards) encourage both incremental and radical innovations. Innovativeness is sensible to environmental policy stringency
Christiansen (2001)	Norwegian carbon tax system in the oil industry	Regulatory instruments (taxes) foster the diffusion of available technologies and incremental process changes
Similä (2002)	Impact of Water Act in the Finnish pulp & paper industry	Economic instruments (water permits) affect compliance and innovation choices
Frondel et al. (2004)	End-of-pipe and integrated process changes in Germany	No significant impacts of economic instruments. Regulatory instruments are important especially for end-of-pipe solutions Stringency is the most significant determinant of EIs.
Nill and Tiessen (2005)	US automotive sector	Regulatory instruments (standards) influence the competition between technological alternatives. Timing and stringency affects variation-selection dynamics
Taylor et al. (2005)	SO_2 control technologies in US	Economic instruments (emission trading) have a limited impact on innovation
Johnstone (2007)	Role of environmental policy initiatives on environmental innovation	Policy instrument choice does not directly affect environmental performance
Mickwitz et al. (2008)	Pulp and Paper and the marine engine industry in Finland	Regulatory instruments (taxes) drive diffusion and innovation.
Brouillat and Oltra (2012)	Impact of three types of extended producer responsibility instruments (i.e. recycling fees, tax subsidy and norms) on EIs	Only tax-subsidy systems can lead to radical innovations and to significant changes in product designs.
Jang et al. (2015)	Policies related to EIs in 17 Asian countries	Coordination of different environmental policies is necessary to foster EIs

Source: own elaboration

3.2.1.2 EIs and the effectiveness of environmental policy

Along with the type of policy instrument employed, the effectiveness of environmental policy driving EIs may be affected by the policy design (in terms of stringency and predictability) as well as by the companies' capacity to comply with environmental measures. A high degree of stringency represents a relevant condition to induce companies to eco-innovate (Arfaoui et al., 2014; Brouillat and Oltra, 2012; Johnstone and Hascic, 2009; Kivimaa, 2008). In a recent study, Ghisetti and Pontoni (2016) find that regulatory stringency represents the most relevant determinant to drive the eco-innovative behaviour of companies. From a global regulatory perspective, it is possible to argue for a positive relationship between stricter environmental regulations and companies' competitiveness since firms can gain a 'first mover advantage' if other countries take time to adapt to regulation (Chassagnon and Haned, 2015). Similarly, predictability, the degree to which future environmental policies can be foreseen, may have a positive influence on EIs by reducing risks and uncertainty of the eco-innovating process (Bernauer, 2006). Findings from Triguero et al. (2013) and Horbach et al. (2012) seem to confirm the high relevance of expected future regulations for the eco-innovative behaviour of companies. Krozer (2008, pp. 114-118) identifies a 'policy cycle' and an 'eco-innovating cycle' as a consequence of an expected environmental policy, which are rigorously connected with each other (Table 4).

Table 4 Environmental policy and eco-innovating cycles

Policy Cycle	1. Signalling period 2. Preparation period 3. Implementation period 4. Evaluation period
Eco-innovating cycle	1. Technology development period 2. Waiting period 3. Sales period 4. Maturation period

(**Source**: Krozer, 2008)

The policy cycle generally begins with the signalling of negative effects on the safety and health of environmental degradation from some interest groups (local communities, environmentalists, experts etc.). When signals are particularly

strong they build social and political pressure to trigger policy preparation. The signalling period generally lasts a couple of decades, during which research is undertaken with the aim of proving the necessity of an environmental policy. At the same time, some companies begin to eco-innovate in accordance with their predictions of future regulations. At the end of the signalling period, political authorities start to prepare the environmental policy supported by qualified experts who compare technologies that can be used to tackle the signalled problem (including the EIs developed during the signalling period) and verify their performance to identify the best available technology. Overall, the preparation period may last more than 10 years and ends with the announcement of a directive that provides the legal basis for the enforcement of the environmental regulation. During the implementation period, innovators sell the technologies approved by policy makers, although the sales may remain uncertain since the new technologies may not be the best performing ones. The policy cycle ends with the evaluation of the results obtained and the preparation of new policies based on the results achieved, new studies, research, growth of production, etc. When a company decides to bring future environmental regulations forward, the eco-innovating cycle begins.

The first stage is characterised by the development of some EIs and generally starts about halfway after the signalling period and ends in the early years of the preparation period. At this stage, eco-innovating companies face a major level of uncertainty, since their eco-innovative investments might not give the expected results. If some positive result is reached, companies begin to promote their EI, although they might not be able to sell it since customers may wait until the regulation is enforced.

During the implementation period, eco-innovating companies begin to sell the EI developed: the sales period may start immediately if demanders of the EI have an interest in buying and using the EI. Finally, the ‘maturation period’ is the sum of the waiting time and the time to achieve the median of sales. It accounts for the number of years necessary to gain half the total potential sales revenue during the implementation period. Overall, the time between the eco-innovative investment and sales saturation can last up to 20 years. According to Krozer,

the ‘enforcement’ and the ‘waiting’ periods (along with the level of interest rate) determine the profitability of EIs for companies: the longer the two periods, the less profitable are the EIs. Since the type of policy instrument adopted influences these two factors, the choice of the environmental measure seriously affects the profitability of eco-innovative investments. For instance, profitability may increase in the case of tradable permissions (given their shorter enforcement period), and subsidies (because of the lower investment in R&D), but decreases in the case of emission charges, since they cause higher interest rates.[10] Finally, the capacity of companies to comply with environmental measures contributes to creating favourable conditions for policies to succeed (Florida et al., 2001, Bernauer, 2006). This, in turn, depends upon the ‘green capabilities’ of companies, i.e. their attitude towards the knowledge of environmental issues as well as the procedures for acting and reacting to these issues, such as quantity and quality of human resources that deal with the environmental matter and/or have specialised environmental expertise (number, tenure, experience of staff, etc.), type of business practices (e.g. company’s previous experience with environmental certification), existence of performance monitoring systems to monitor environmental performance and company outcomes (environmental cost identification, use of control processes, environmental inspections, environmental supplier audits, etc.), and a company’s management capacity.

When a company faces an emerging environmental demand, the management can opt between compliance or anticipation strategies by searching for eco-innovative solutions. The option to eco-innovate is uncertain in terms of costs and benefits, but possibly rewarding. In other words, managers face some ‘changeover costs’, i.e. the entire costs connected with the efforts related to the preparation of the investment before using the EI. Since changeover costs are made despite uncertainty regarding the innovation performance, this helps to

[10] Krozer simulates the effects of different environmental policy instruments on profitability of EIs according to several waiting and enforcement periods. His findings suggest the lack of the best policy instrument from the point of view of the eco-innovating company. Regardless the type of policy instrument adopted, the positive effects on eco-innovativeness of companies largely depends on the possibilities of reducing the waiting period and speeding up the implementation (Krozer, 2008, pp 124-125).

explain the bias against EIs. In this regard, Krozer (2008) argues that companies eco-innovate only if they can predict policymaking: this means that environmental policy should be announced in advance in order to allow changes-over and reduce companies' uncertainty.

3.2.2 Market structure

The existence of a relationship between market structure and companies' innovativeness is well recognised in the literature although there is no consensus regarding how the degree of concentration affects the eco-innovative behaviour of companies (Galliano and Nadel, 2015). From a Schumpeterian perspective, the relationship between market power and innovation is positive due to the possibility of companies with market power enjoying superior access to capital, ability to pool risks, and economies of scale in maintaining R&D laboratories (Brunnermeier and Cohen, 2003). When a company dominates a market it should be able to more easily finance its R&D investments (Marlin and Scott, 2000). Furthermore, in the presence of market power, innovating companies can appropriate the innovation rents by implementing market barriers to prevent imitation as well as by patenting their innovations (Horbach, 2008). By contrast, some studies (see, for instance, Beise and Rennings, 2003) find evidence that market concentration may hinder innovation activities, since the incentive to innovate may decrease once monopolistic rents are secured. Moreover, the intensified competition in the globalised markets encourages companies to find new market opportunities, to create new products, to adopt new production processes, etc. From this point of view, investments in EIs can represent a strategy for companies to differentiate from their competitors and achieve a better position in the market (Díaz-García et al., 2015; Triguero et al., 2013; Bernauer, 2006). In this framework, a number of new and older studies (Cainelli and Mazzanti, 2013; Horbach et al., 2012; Green et al., 1994; George et al., 1992; Schot, 1992) emphasise the role of company suppliers and industry organisations as drivers of EIs, by stressing the importance of the interactions across the chain of production for projects resulting in environmentally friendly products.

3.2.3 Market demand for green goods and services

Another significant external-to-company driver of EIs is represented by the market demand for green goods and services. In recent years, climate change concerns have become critical and the increasing value assigned by individuals to environmental preservation has brought a greater demand for environmentally friendly products (Chassagnon and Haned, 2015). The diffusion of information on the life cycle performance of products and on the environmental impact of toxic substances and polluting emissions has certainly contributed to this growing trend (Oltra and Saint Jean, 2007). Nowadays, many consumers tend to follow a number of environmental criteria in their purchase decisions concerning toxicity of products, recyclability, eco-efficiency, emission-related performance, etc., avoiding purchases from companies that do not have acceptable environmental practices (Chen, 2001). Such 'green consumers' can drive companies to eco-innovate, pushing them to include environmental attributes (such as material selection, package design, energy and solvent usage, etc.) in the design process of their products and/or by acquiring quality assurances for environmental management (ISO 14000, EMAS, etc.). Indeed, a number of studies (Segarra-Oña et al., 2015; Hall and Martin, 2005; Heinelt et al., 2003; Clarke and Roome, 1999; 1995; Roome, 1994) have shown that the 'green demand' for goods and services increases companies' eco-innovativeness by raising management awareness of the need to integrate environmental issues in the product development. However, some investigations (see, for instance, Kesidou and Demirel, 2012) have found evidence that the green demand triggers companies to undertake EIs but not to invest heavily in them. Moreover, findings from Li (2014) suggest that pressure from foreign customers works better than pressure from domestic customers as a EIs' driver.

Green consumers can also join in pressure groups (e.g. environmental movements) to make companies liable for unsafe and hazardous operations and to push them to pollute less (Frondel et al., 2004). They can also drive EIs indirectly by exerting pressure on governments to implement more stringent environmental regulations. In this framework, EIs represent for companies a

way to improve their image and, thus, foster their relation with consumers (Triguero et al., 2013; Kemp and Andersen, 2004; Rothwell, 1994).[11] In some circumstances, customers can actively contribute to EIs manufacturing. Del Brio et al. (2007), for instance, suggest that the capability of customers to act as co-manufacturers represents a key-element to improving, both, the environmental performance and competitiveness of companies. Indeed, the literature stresses that EIs are more cooperation-intensive than general innovations and that customers represent, therefore, a significant source of information and knowledge for companies in order to engage in eco-innovative projects (Horbach et al., 2013; De Marchi, 2012; Yarahmadi and Higgins, 2012).

3.2.4 Company size

A relevant internal-to-company driver of EIs is represented by company size, which may drive companies to different levels of innovativeness (Ghisetti and Pontoni, 2015). The question of whether small and medium enterprises (SMEs) are more innovative than the larger ones (or *vice versa*) has been the subject of a great deal of controversy and research (Connell and Flynn, 1999). SMEs may be more innovative than larger companies given their flexibility and their major willingness to undertake new challenges and changes. Thanks to their increased adaptation capacity, SMEs can react more rapidly to new situations with respect to their larger competitors. Moreover, being a SME could foster radical innovations due to the lower cost of replacing older technologies and greater learning capacity (Galliano and Nadel, 2015).

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[11] The negotiation between pressure groups and companies represents a central topic in environmental economics. The idea is that the allocation of property rights for social goods, such as the environment, involves negotiations between private interests, leading to economic efficiency without any government intervention independent of the initial allocation of rights (Coase, 1960): the task of policy makers is only to define the rights and to provide the legal framework for negotiations. However, the 'Coase theorem' (as well as negotiation theories in general) has been heavily criticised not only for its typical neoclassical shortcomings in dealing with environmental problems (see sections 2.3, 2.4, and 2.5), but also since it supposes a number of starting conditions that are unlikely to be met (e.g. few parties affected by the environmental externality, perfect knowledge of people involved, well specified property rights, not costly or time consuming negotiations, etc.) (Dutilh, 1995).

In contrast, SMEs may lack financial means, access to credit, economies of scale for innovative activities, education and training resources, ability to establish new relations, vision, etc. In the case of EIs, company size can represent a relevant factor to drive eco-innovativeness. Firstly, the capacity of companies to eco-innovate largely depends on access to information about the environmental risk of their activities (OECD, 2009a). From this point of view, large enterprises have more resources to enhance their ability to possess and process environmental information (De Marchi and Grandinetti, 2013; Sharma, 2000; Russo and Fouts, 1997). Secondly, size can reflect the extent to which companies are visible to the public. In particular, larger companies can be perceived as being more environmentally risky than SMEs and, hence, they can be spurred to eco-innovate, since they receive a great deal more attention from media and stakeholders (Hofer et al., 2012; Beveridge and Guy, 2005; Cohen et al., 1995). By contrast, the environmental impact of SMEs is most often overlooked and therefore they can be less eco-innovative than larger companies (Van Hemel and Cramer, 2002). Finally, changes in environmental regulation can generate significant information burdens and adaptation costs for SMEs, which need to invest time and resources to acquire relevant information, understand the implications of new regulations and consistently adapt their products and processes.

Empirical evidence on the impact of company size on eco-innovativeness is mixed. Some authors (Kesidou and Demirel, 2012; Elsayed, 2006; Roy et al., 2001; Toms, 2000; Pava and Krausz, 1996) have found evidence that larger companies are more likely than SMEs to be eco-innovative. However, results produced by Revell et al. (2010) and Stanwick and Stanwick (1998) suggest that SMEs are more environmentally responsive than larger companies. Finally, Wagner (2008), Waddock and Graves (1997), Roberts (1992), and McGuire et al. (1988) find evidence that size does not produce any significant impact on environmental orientation of companies. It is worth noting that the impact of company size upon eco-innovativeness is found for both incremental and radical EIs (Galliano and Nadel, 2015). Only Demirel and Kesidou (2011) find that company size affects exclusively the firm’s propensity to carry out incremental but not radical EIs.

3.2.5 Cost-savings

Finally, a significant driver of EIs is represented by expected cost-savings of enterprises (Hojnik and Ruzzier, 2016; Pereira Sánchez and Vence Deza (2012). By eco-innovating, companies can rationalise the amount of inputs employed in their production process, thus reducing energy, material, waste treatment costs, etc. (Horbach et al., 2013; Park, 2005). Cost-savings relate therefore to the concept of 'eco-efficiency, i.e. getting more for less. From this viewpoint, Andersen (2010) points out that EIs allows to attract green rents for companies by reducing production costs to achieve greater resource efficiency. Indeed, resource inefficiency can be particularly costly to enterprises. A study from the UK Environment Agency (2005), for instance, estimates that £2 - 3 billion of natural resources are wasted each year in the manufacturing industry, equivalent to about 7% of total manufacturing profit. The possibility for companies to recognise the cost-savings associated with any eco-innovative effort may be enhanced by the implementation of well-designed environmental regulations and by the existence of 'green capabilities' within companies, i.e. their attitude towards and knowledge of environmental issues, as well as the procedures for acting and reacting to these issues (Bernauer, 2006).

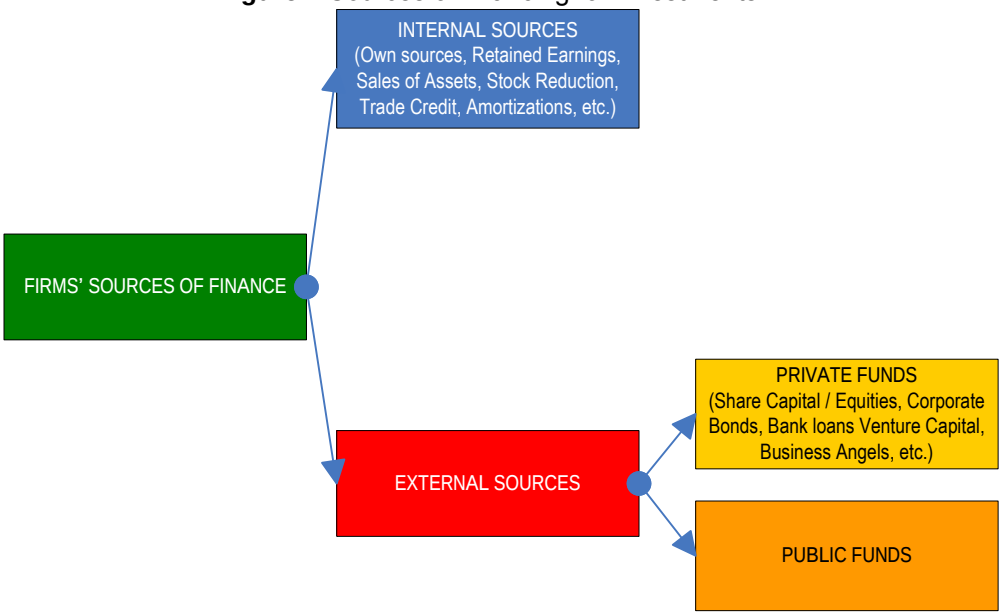
3.3 Capital structure and the theory of hierarchy of finance

From the analysis of EIs' drivers reported in section 3.2, the lack of former investigations about the role of companies' financial resources as possible drivers or barriers to their eco-innovative decisions emerges. The importance of finance for innovations has been recognised since 1912, when Schumpeter argued that 'new combinations', as generally provided by companies, require external finance: '*while granting credit is not essential in the normal circular flow...it is certain that there is such a gap to bridge in the carrying out of new combinations. To bridge it is the function of the lender, and he fulfils it by placing purchasing power created ad hoc at the disposal of the entrepreneur*' (Schumpeter, 1912, 1934). Later he added that: '*major innovations and also many minor ones entail construction of new plant (and equipment) - or the rebuilding of old plant - requiring non-negligible time and outlay*' (Schumpeter 1939: 68). After Schumpeter, literature has focused mainly upon two lines of research. The first investigates the relevance and performance of financial environments for economic growth, by emphasising the importance of financial development of countries (see, for instance, Aghion et al., 2010; Beck, 2009; Bekaert et al. 2005; Demirgüç-Kunt and Maksimovic, 2002). The second analyses the financial decisions made by innovating companies, starting from the consideration that innovations require a considerable degree of immobility of companies' finances (Spielkamp and Rammel; 2009; Lazonick, 2004; O'Sullivan, 2004; Lazonick and O'Sullivan, 1996; Santarelli, 1995; Christensen, 1992). In this framework, many authors have specifically investigated the impact of financial constraints upon the innovation activity of enterprises such as, for instance, Mancusi and Vezzulli (2014), Savignac (2008), Stockdale (2002), Hall (2002), Mulkay et al. (2001), Kaplan and Zingales (2000), Bond et al. (1999), Bond and Meghir (1994), and Fazzari et al. (1988). This section starts by discussing the capital structure of companies with particular reference to the financial options provided by the green finance to the eco-innovative enterprises. Then it moves towards the analysis of the financial constraints by presenting the problem of the hierarchy of finance.

3.3.1 Capital structure and green finance

To finance their overall operations, enterprises may recur to internal and/or external funds. The different sources of funds employed represent the capital structure of companies. The capital structure can thus be defined as the configuration of financing instruments that companies employ to fund their assets and constitute the liabilities side of their balance sheet. The internal financing of companies derive from their own sources: retained earnings, sale of assets, stock reductions (i.e. the selling of raw materials, semi-finished products, and finished products not yet sold), advance payments, and possibly tax credits achieved through amortisation or other accounting practices.. External financing is represented by private funds (share capital/equities, corporate bonds, bank loans, business angels, venture capital) and/or public support (Figure 4).

Figure 4 Sources of financing for investments



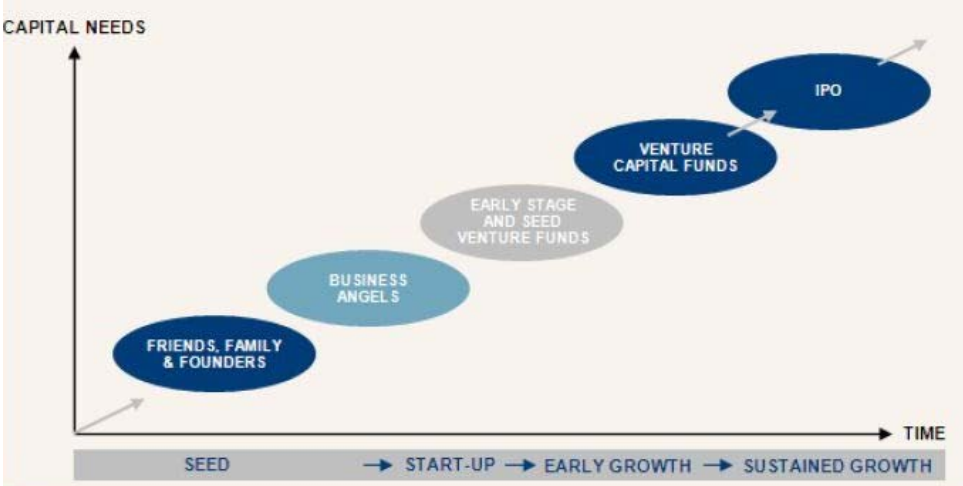
(**Source**: own elaboration)

In this framework, financial markets and intermediaries (banks, insurance companies, etc.) pay greater attention to eco-innovative projects, not only by providing new options of external private sources to eco-innovative enterprises, but also by integrating environmental criteria into the lending process.

Funding options of eco-innovative companies

In the financial markets, Business Angels (BA) and Venture Capital (VC) may be increasingly active in offering finance for start-up companies operating in the environment/recycling/cleantech related sectors (EIM and Oxford Research, 2011). Such 'green BA' and 'green VC' represent an emerging phenomenon whose number and variety are expected to increase in the next years. They are particularly useful to fund radical EIs in their early stage or expansion, when future returns on investment cannot be easily estimated (Courvisanos, 2008; Goodacre and Tonks, 1995; Fox, 1987). Specifically, green BA focusses on eco-innovative investments that are too small for venture capitalists, that involve longer time horizons or that have more modest return expectations (Van Osnabrugge and Robinson, 2000). Therefore, they play a significant role in filling the gap between the initial investment and the first round of VC along the financing chain (Figure 5).

Figure 5 An example of a financing chain



(**Source**: EIM and Oxford Research, 2011)

Similarly, green VC are extremely important in the early stages of the eco-innovating process. Unlike mainstream VC, which can include environmental issues in their investment decision procedure as a risk factor only, green VC consider the capacity of EIs to add value to companies, besides the risk reduction factor (Randjelovic et al., 2003). Therefore, green VC generate a 'double dividend' since they provide low environmental impacts or risks along with financial returns. Data provided by the Clean Tech Group show that Europe and Israel accounted for €1.1 billion in 2009 (28% of the total amount of VC

funding raised), compared to €2.6 billion (64%) in North America. However, in Europe, up to 39% of VC were represented by green VC, twice that of North America where the percentage was between 17% and 20% . Within Europe, the UK is the largest green VC market (followed by Germany, Norway, and France) and its principal investments are in the field of energy generation and energy efficiency. However, despite such figures, green VC still cover only small percentages of the total amount of EIs finance across the world (OECD, 2008). Also banks are progressively orienting towards eco-innovative companies by developing green financial products and services aimed at providing eco-innovating enterprises with easier access to capital, as summarised in Table 5.

Table 5 Examples of green financial products and services developed by banks

Function	Particulars	Product
Lending	Financing investments in eco-innovative projects	Preferential banking package
	Environmental mortgages	Lower interest rates
	Organisations fulfilling certain ecological criteria	Environmental rating and due diligence checks
Advisory service	SME	Environmentally related counselling
Leasing	Making government fiscal schemes accessible to entrepreneurs	Purchase and subsequent lease of environmental products

(**Source**: adapted from Labatt and White, 2002)

It is worth noting that products and services reported in Table 5 have been recently adopted not only by larger financial intermediaries, but also by smaller and niche market-oriented banks, although the number of opportunities to integrate environmental aspects into the financial services still remains largely unexploited (Labatt and White, 2002).

The integration of environmental criteria into the lending process

Along with providing new funding options to eco-innovative companies, financial markets and intermediaries are increasingly integrating environmental criteria into the lending process. In the financial markets, environmental concerns are becoming an additional and significant (non-financial) criterion with which green investors base their investment decisions (Knörzer, 2001).

Initially, the environmental selection techniques focused on screens that barred investment in companies belonging to specific sectors, such as nuclear power, and in those companies that had attracted adverse attention because of environmental pollution. Later, green investors started to include also positive elements in their investment decisions that allowed for investment in pioneering eco-innovating companies (Ganzi and DeVries 1998). Nowadays, the screening strategies of green investors involve the selection of companies according to their environmental performance and irrespective of the economic sector. In this framework, only companies with the best environmental records are eligible for investment consideration. For this reason, many portfolio managers balance the greater risk perceived in the use of non-financial screens with the inclusion of more established stocks in the major green industrial sectors, in order to be eligible for investment consideration on environmental grounds (Elkington and Beloe, 2000). Very frequently, companies are screened according to eco-efficiency criteria which are perceived as a proxy for superior profitability: the basic idea is that eco-efficiency underlines the existence of strategic and operational ability of a company's management to identify and take advantage of upside opportunities that contribute to shareholder value and competitiveness (EPA, 2000). However, green investments still represent a niche within the investment fund markets. For instance, in the EU, they amounted to €129.49 billion in 2010, which was only 1.6% of the total assets of the investment fund market (KPMG, 2012). Within the universe of green investment funds, climate change, renewable energies, ecological fuel, and water are the four largest thematic sub-categories in terms of assets under management. Among the financial intermediaries, banks and insurance companies are developing evaluation criteria to assess environmental risks associated with the financial services that they provide to customers. For instance, many banks classify industrial sectors into different categories according to the magnitude of the environmental issues, providing different extensions of credit to these various categories (Table 6).

Table 6 An example of risk assessment for extension of bank credit

Category I (low environmental risk)	**Category II** (medium environmental risk)	**Category III** (high environmental risk)
Dry cleaners (depot)	Dry cleaners (facility)	Chemical and petrochemical industries
Electric substations	Electrotechnological industries	Fertilisers
Furniture and fixtures	Fabricated metal products	Foundries
Laundry and garment services	Farming industries, services and supplies	Oil and gas production
Leather and leather products	Galvanising industries	Pesticide/fungicide/ herbicide manufacturers
Lumber and wood products	Garages for repairs (cars/buses/trains)	Petroleum refining
Printing and publishing	Ink manufacturing	Pulp and paper industries
Stone, clay, and glass products	Metallurgic industries	Resource extractive industries
Textile industry	Mining	Steel
Warehousing	Oil and gas exploration	Waste management
	Oil and gas products manufacture	Wood preservation
	Paint/lacquer manufacture	
	Petroleum bulk stations/terminals	
	Pharmaceutical industries	
	Pipelines (excluding natural gas)	
	Pipelines (natural gas)	
	Plating companies	
	Recycling plants handling solvents batteries, used oil, or liquid waste	
	Scrap and waste materials industries	
	Service stations	
	Shipyards	
	Tanneries	
	Transportation industries	

(**Source**: Labatt and White, 2002)

3.3.2 The theory of Hierarchy of Finance

The problem of how to finance an investment project (i.e. whether to resort to internal or external financing and, in the latter case, whether to incur debts or equity) represents a crucial decision for companies (Santarelli, 1995). In this regard, companies seem to exhibit a strict ordering or Hierarchy of Finance (HoF) by using internal financing first, then debt, and only when such options are exhausted, is equity considered (Myers, 1984). The preference for internal rather than external financing is explained by the fact that these two sources of financing are not perfect substitutes and can thus determine companies' risks of being financially constrained (Giudici and Paleari, 2003; Gompers and Lerner,

1999; Manigart and Struyf, 1997; Moore, 1994; Himmelberg and Petersen, 1994). Within the external financing, the preference for debts rather than for equity is explained based on different theories, such as the tax-based and agency cost theories and the asymmetric information theory (Michaelas et al., 1999). These empirical observations regarding practice and supplemental theories depart from the neoclassical conclusions reached by Modigliani and Miller (see next subsection).

3.3.2.1 The imperfect substitutability between internal and external financing and the problem of financial constraints

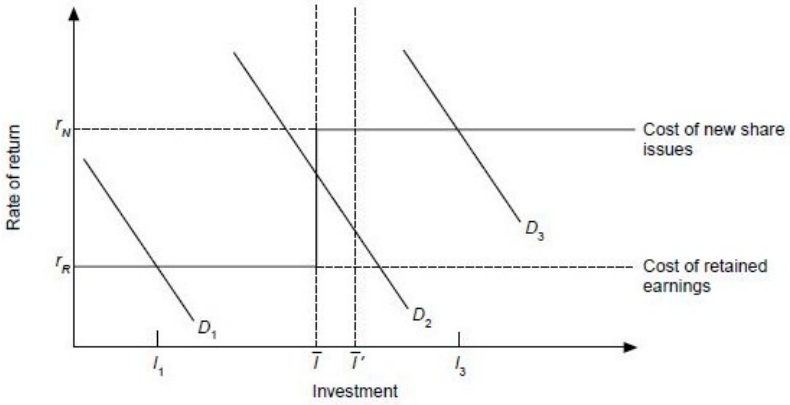
In the absence of capital market friction the cost of internal and external funds should be the same, so that profitable investments should always be funded even if project costs exceed internal funds. According to Modigliani and Miller (1958) the total value of a company is independent of the structure of ownership claims, i.e. a company's capital structure is irrelevant to its value. This means that, from a financial viewpoint, companies' investment decisions should be independent of their financial choices, but dependent only upon the availability of investment projects with positive net returns. However, financial markets suffer from two key market imperfections. Firstly, management has information about investment projects that investors do not have ('hidden information problem'). Secondly, investors cannot see all actions that managers take once the project is financed ('hidden action problem'). Since the extent to which a company can raise funds largely depends on the cash flows that the capital providers believe they can accrue, investment projects that would be financed in perfect capital markets may not be in imperfect capital markets, since fund providers may not believe that they will receive sufficient cash flows from the investment. The existence of differential information and incentive problems determines a positive gap between the internal and external cost of capital and the preference for companies to finance their investment projects by internal capital, which is available at a lower cost than external finance (Marabel Romo,

2014; Canepa and Stoneman, 2003; Hall, 2002).[12] In debt markets, information asymmetries make lenders unable to reliably price discriminate (i.e. to vary the interest rates) between good and bad borrowers in loan contracts. When interest rates increase, good borrowers drop out of the market, increasing the probability of default and decreasing lenders' expected profits, and therefore cause credit rationing (Stiglitz and Weiss, 1981; Keeton, 1979). In equity finance, when new shareholders are not fully informed about the value of a company's assets and investment opportunities, then they will demand a premium to purchase the shares of relatively high-quality companies to offset the losses arising from funding 'lemons' (see, for instance, Fazzari et al., 1988; Myers and Majluf 1984; Greenwald et al., 1984). This premium raises the cost of new equity finance faced by managers of relatively high-quality companies above the opportunity cost of internal finance faced by existing shareholders. Therefore, the imperfect substitutability between internal and external financing, arising from asymmetric information, financially constrains companies through a shortage of internal funds. Financial constraints (henceforth FC) are therefore frictions that prevent companies from funding all their desired investments. They should not be confused with financial distresses or bankruptcy risks, although these are undoubtedly correlated with FC (Saá-Requejo, 2001).

The risk of companies being unable to fund their desired investment is well described by Bond and Meghir (1994). The authors initially consider the case of a company that does not have access to debt finance and therefore must choose between retained profits and new shares to finance an investment project (Figure 6)

[12] Along with asymmetric information, other reasons can explain the preference of companies for internal rather than external financing. In particular, internal financing does not involve the issuance costs of debt and equity, which can be prohibitively high for some companies. Additionally, the issuance of debt or equity can cause agency problems to arise, as will be discussed in section 3.3.2.2.

Figure 6 The HoF finance model with no debt finance



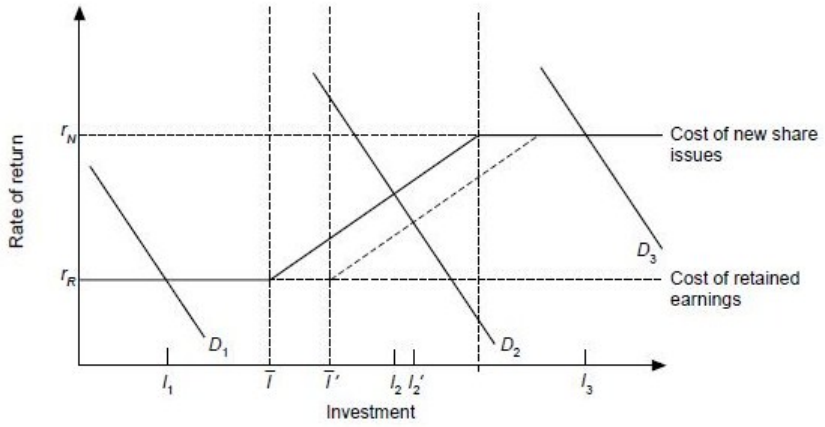
(**Source**: Bond and Meghir, 1994:5)

Suppose that r_R and r_N are, respectively, the cost of finance from retained earnings and from new share issues, and that D (D_1, D_2 and D_3) are the investment opportunities available to a company, and $\bar{I}$ is the maximum level of investment that a company can finance from its internal sources.[13] For a company with low profitable investment opportunities relative to its cash flow, the position of the investment demand curve will resemble D_1 and the corresponding investment spending will be I_1. Similarly, for companies with very high profitable investment opportunities relative to their cash flow, the position of the investment demand curve will be like D_3 and the corresponding investment spending will be I_3. Since such companies have sufficiently attractive investment projects, they issue new shares, despite the extra cost. FC affect the investment spending of companies in the intermediate position (line D_2): such companies have sufficiently attractive investment opportunities and they exhaust all their internal sources of funds available for investment on these, although their remaining projects are not sufficiently attractive that they would choose to issue new shares, given the higher rate of return required. In such cases, the companies are financially constrained since an increase in cash flow would produce an increase in investment spending (from $\bar{I}$ to $\bar{I}'$) as companies move down the demand curve D_2. Such results do not change in

[13] $\bar{I}$ does not necessarily correspond to the point at which dividend payments have been reduced to zero: since dividend payments are 'sticky' downwards, $\bar{I}$ can be thought as the point where the company is unwilling to cut its dividend payments any further.

case debt (instead of new equity) is employed as a source of external finance (Figure 7).[14]

Figure 7 The HoF model with debt finance



(**Source**: Bond and Meghir, 1994: 8)

For companies with profitable investment opportunities, particularly low (D_1) or high (D_3) relative to their cash flow, the implications are broadly the same as in the no-debt case (except that both kinds of companies may use some debt in addition to retentions or new shares to finance their investment). Companies that exhaust their internal funds and do not issue new shares (D_2) are no longer constrained to the level of investment spending $\bar{I}$: their investment depends upon the rising cost of debt that they face, giving the I_2 level. It is worth noting that in such cases, companies are still financially constrained, since an increase in cash flow allows levels of investment above $\bar{I}$ to be financed at lower levels of borrowing. This reduces the effective cost of debt at each investment level, resulting in higher investment at I_2.

3.3.2.2 Tax-based and agency cost theories

Tax-based and agency cost theories contribute to explaining, within external financing, the preference of companies for debts rather than for equity. Both

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[14] The authors explain the increasing effective cost of borrowing because of:

1. the direct and the indirect costs associated with bankruptcy (e.g.: loss of value of intangible assets such as brand names and reputation);
2. the risk premium reflecting asymmetric information between lenders and borrowers that becomes more important as the probability of default increases.

theories assume that companies have an optimal capital structure and that they aim to attain this through a target debt level by substituting debt for equity or *vice versa* until the value of the company is maximised (Myers, 1984). In particular, tax-based theories argue that tax considerations represent the main driver of companies' capital structure decisions (Graham, 2000).

In order to identify their optimal leverage, companies compare costs and benefits of debts, including the tax deductibility of interest and the reduction of free cash flow problems (Fama and French, 2002). In particular, the deductibility of interest payments drives companies towards more bond debt, while favourable individual treatment of income from capital gains relative to interest income drives them towards less bond debt.

Agency cost theories focus on agency costs arising from conflicts of interest between managers and shareholders (principal-agent problem (PA)) or between debt holders and equity holders (Jensen and Meckling, 1976; Fama and Miller, 1972). The first case refers to the separation between ownership and management, which may result in investment strategies that are not share-value maximising since managers may spend on activities from which they only can benefit. The second case refers to the possible asymmetry in risk-sharing between debt holders and equity holders. When an investment fails, debt holders bear most of the cost and this pushes equity holders to prefer very risky projects that have high returns, while debt holders prefer the opposite. Both of these conflicts can be avoided by choosing an optimal capital structure. By increasing a company's debt, managers have less cash flow available to engage in activities for their personal gain (Jensen, 1986). Moreover, debt increases managers' ownership of the company. When a company is mainly financed by debt, it consequently relies less on equity, which in turn implies that the equity ownership of managers in the company increases relative to shareholders. This should push managers to act in the interest of the company (Jensen and Meckling, 1976).

3.3.2.3 Asymmetric information theories

Finally, asymmetric information theories attempt to explain the preference of companies for debt rather than for equity by taking into account the 'hidden information' problem. This can be reduced through market signalling, which consists of signals conveying information (that managers send to investors) about the quality of investment projects to finance, a possibility recognised in Spence's (1974) work. Because of the risk of imitation of inventive ideas, companies are indeed reluctant to fully reveal their innovative efforts to the marketplace and this reduces the quality of the signal that they can announce about their investment project (Hall, 2004).

In this framework, capital structure can represent a useful way to send credible information to prospective investors since the preference for debt rather than equity signals to investors that the company's investment will indeed pay off and that the company is able to fulfil its debt (Ross, 1977). Suppose a population of companies, where each company is either high or low quality, (a high quality company has a larger NPV for its current operations than the low quality one), and where only managers know whether companies are high or low quality. Moreover, suppose that each company has an opportunity to undertake a profitable investment (whose cost is the same for each type of company), on the condition that the company will raise capital to finance the new project. Prospective investors know the NPV of the new project but they cannot determine whether a particular company is high or low quality. As argued by Akerlof's 'Market for lemons' model (1970), the maximal price investors will be willing to pay for the new shares depending on the average of the NPV of high and low quality companies, including the new project, weighted by the number of each company type in the total population. Consequently, the proportion of a high quality company that new investors acquire would be larger if the managers of the high quality company could credibly inform the new investors that the shares they are acquiring actually belong to a high quality company.

In other words, from the perspective of a high quality company, the presence of low quality companies contaminates investor expectations. Thus, the

shareholders of a high quality company will not undertake the project since they would lose wealth, because the new investors would acquire too large a proportion of the company's value. This means in turn that the hidden information between managers and investors allows only the low quality companies to finance the investment by selling new shares. Consequently, if a high quality company has no access to financing other than by selling new shares, that company must forego its project. The problem of asymmetric information can be overcome if either type of company can choose between issuing equity or bonds to finance their projects. Since investors can predict the impact that enterprises' decisions on how to finance the project will have on the wealth of companies' current shareholders, managers of high quality companies can issue bonds to finance the new projects while managers of low quality companies can issue equity. In this way, investors will distinguish the high from the low quality companies based on their financial choices. Consequently, companies can finance their project without imposing any net transfer of wealth between current shareholders and new investors. Similarly, if companies have enough initial wealth to finance their investment, they may signal to investors that their project is sustainable by self-financing a fraction of their project, given that the companies with low-quality projects would not have any interest in doing the same. It is worth noting that signalling is a costly process: by financing a fraction of their projects, companies lose income, which represents the informational cost of capital. Diamond (1984) argues that if borrowers form a coalition (partnership or intermediary), the unit cost of capital decreases with the size of the coalition itself.

3.3.2.4 Empirical evidence

The empirical studies that have tested the HoF model and the existence of FC related-problems have so far produced mixed results (Hubbard, 1998; Schiantarelli, 1995). Such studies can be classified into two different groups according to the way FC are measured.

The first group collects studies that have proxied FC by means of 'indirect' measures, which are generally gathered from secondary data. The most

widespread indirect measure of FC is represented by cash flow variables, employed as proxies of internal funds availability. Results produced using such measure are mixed: some studies (Mulkay et al., 2001; Himmelberg and Petersen, 1994) suggest significant cash-flow sensitivity of companies' investment decisions while others (Harhoff, 1998; Bond et al., 1999) provide evidence of the opposite. It is worth noting that results from comparative studies suggest that the Anglo-Saxon economies (which are characterised by thick and developed stock markets and relatively transparent ownership structures) exhibit a greater sensitivity of R&D to cash flow than continental economies (Hall, 2002). However, such greater responsiveness may arise not only because companies in such economies are financially constrained but also because they are more sensitive to demand signals in thick financial equity markets. Indeed, a correlation between cash flow and investment does not suggest univocally that investment spending is constrained by the availability of internal funds, since investment is likely to depend not only on the current level of optimal capital stock, but also on the level of capital stock that companies expect will be optimal in the future (Gomes 2001; Kaplan and Zingales 2000, 1997; Cleary, 1999). For this reason, the HoF model was tested also by exploiting the relationship between investment rates in successive periods implied by the costs of the adjustment model, i.e. by using an intertemporal condition relating investment in the two next periods (Euler equation).

For instance, Bond and Meghir (1994) find evidence that the investment spending of companies is affected by the availability of their internal finance. When data on expectations are not available, the existence of FC was alternatively tested employing the Tobin's Q, which assumes that investment is likely to be higher when the market valuation of the company's capital is high relative to its replacement cost. If financial variables are found to be significant determinants of investment in addition to the measure of Q, then it is reasonable to infer that these terms sufficiently describe the influence of FC. In this regard, Hayashi and Inoue (1991) find evidence that cash flow has a positive and highly significant effect on company investment in addition to measured Q. Similar conclusions can be drawn from the studies of Blundell et al. (1992) and Fazzari et al. (1988). Finally, Hoshi et al. (1991) investigate

whether the HoF model may be less important where banks maintain long-term relationships with companies. The authors divide their sample into two groups according to whether companies have a close relationship with a bank or not, finding that cash flow is less significant for the sub-sample of companies that are closely related to a bank.

The second group investigates the HoF model by using direct measures of FC generally gathered by means of surveys. Despite the well-known drawback in the use of surveys to investigate FC (indeed it is reasonable to suppose that companies surveyed declared being financially constrained because of their desire to have more funds at lower prices), these studies allow overcoming the problem of interpreting results that arise from the use of proxies. In general, findings achieved by using direct measures seem to univocally confirm the existence of FC to companies' innovativeness. Stockdale (2002) reports findings from the third Community Innovation Survey (CIS) for the UK showing that FC are the second most important inhibiting factor for innovation, next to high innovation costs.

Using survey data collected by the Banque de France and Eurostat, Hajivassiliou and Savignac (2007) analyse the impact of FC as a barrier to the innovation activity of companies. The authors conclude that FC discourage innovation and, at the same time, innovative companies are more likely to be financially constrained. Savignac (2008) uses a French company survey based on the CIS methodology to examine the impact of financial barriers on innovative activity: his results suggest that the likelihood that a company has innovative activities is significantly reduced by the existence of FC (more than 20%, everything else being equal). The author is one of the first to control for possible endogeneity of FC by distinguishing between non-innovative companies that seek to innovate and non-innovative companies that do not seek to innovate.

Similarly Tiwari et al. (2007) correct for endogeneity and find that FC are the major obstacle in the pursuit of R&D, and that older companies as well as companies that do belong to a group are less likely to be financially constrained.

Campello et al. (2010) use information from a special survey of chief financial officers to study the effects of FC on real corporate actions because of the recent global credit crisis. Their findings show that 86% of constrained companies have restricted their pursuit of valuable projects, and more than half were forced to delete valuable investments.

By using CIS for Portugal, Silva and Carreira (2011) investigated the extent to which R&D investment and innovation are financially constrained, finding that companies that do not invest in R&D and those that do not receive public funding are financially constrained. More recently, Lahr and Mina (2013) employ innovation surveys for the UK, to investigate the bi-directional causal effects in the relationship between innovation and FC. Their results suggest that innovation activity causes FC while the reverse effect of FC on innovation appears negligible. Mancusi and Vezzulli (2014) investigate the effects of credit rationing on R&D investment using survey and accounting data on a large sample of Italian manufacturing SMEs. After controlling for endogeneity, the empirical analysis reveals that credit rationing has a negative effect on the probability of setting up R&D activities as well as on the level of R&D spending.

Finally, it is worth noting that a residual number of studies has investigated the HoF model by using companies' disclosures. These indicate the possible effects of FC by identifying delays and obstacles in obtaining the desired debt and equity financing in order to avoid investment, at the same time, the risk of biased results stemming from the use of surveys also exists (see, for instance, Ball et al., 2012).

3.3.2.5 The HoF in eco-innovating companies: the role of environmental reputation

Section 3.3.1 has discussed the increased attention paid by financial markets and intermediaries towards eco-innovative projects by providing new options of external private funds to eco-innovative enterprises and by integrating environmental criteria into the lending process. At the same time, in section 3.3.2, it has been argued that the existence of the HoF is mainly attributable to

the presence of asymmetric information problems between companies and prospective investors that causes a strict order of preference in the financing decisions of enterprises and consequent FC problems.

In light of this, a possible way for eco-innovative companies to reduce hidden information could be represented by *environmental* reputation. In general terms, conceptualisations of reputation range from an economic/strategic management informed perspective, which considers reputation as a resource, to a sociologically informed perspective that views reputation as the outcome of shared socially constructed impressions of a company (Bebbington et al., 2008). Fombrun and Shanley (1990) define reputation as the public's affective evaluation of a company's name. In other words, it has some basis in companies' actions but is also constructed by others via their perceptions of companies' activities. More specifically, reputation can consist of, both, economic and non-economic attributes, which are created from a company's past actions. It founds upon the information that stakeholders hold about the company's past performance and may result from their past experience or from information-exchange with other stakeholders (Weigelt and Camerer, 1988). In other words, reputation is essentially inter-subjective, since it is based on a composite of perceptions of a variety of people. Teece et al. (1997) argue that reputation may be more valuable than the true state of affairs in shaping responses of stakeholders. Companies with a good reputation may generally improve relations with external actors, such as investors and bankers (Branco and Rodrigues, 2006), thus limiting the effects of asymmetric information. Similarly, when a reputation-damaging event occurs, stakeholders may react negatively toward the company by lowering their quality of involvement, acting confrontationally toward management, demanding better contractual terms, and/or detaching from the company (Rhee and Valdez, 2009). Thus reputation may represent a strategic asset for a company since it can produce tangible benefits, such as lowering the cost of capital (Fombrun, 1996). Table 7 summarises some of the most significant studies on the importance of reputation.

Table 7 Some studies on the importance of reputation

Authors	Key Arguments and Findings
Barro, Gordon, & Page (1983)	Reputation can act as a surrogate to formal regulations
Rogerson (1983)	Reputation leads to growth in the number of customers due to the reduced defection of current customers
Diamond (1989)	Value of a good reputation increases over time and provides incentives for companies to select less risky projects
Diamond (1991)	Reputation allows borrowers to issue debt without the banks monitoring
Chu & Chu (1994)	Reputation provides retailers with incentive to properly represent quality of products
Dollinger, Golden, & Saxton (1997)	Reputation increases the attractiveness for partners and joint ventures
Preston & O'Bannon (1997)	Higher social performance leads to higher financial performance
Shane & Cable (2002)	Reputation increases companies' attractiveness for prospective funding sources and mitigates the effect of social ties
Deutsch & Ross (2003)	Reputation affects the signalling quality of non-financial attributes to stakeholders

(**Source**: own adaptation from Rhee and Valdez, 2009)

Companies' reputations are generally proxied by means of reputation indexes and ranking studies (*Fortune, Management Today, Financial Times, Reputation Quotient* and *Reputex Social Responsibility Ratings*), which also include indicators of environmental responsibility performance. Toms (2002), Preston & O'Bannon (1997), and Turban & Greening (1997) measure reputation in terms of corporate social performance and treatment of the environment. The authors argue that the positive effects in financial markets that companies achieve from their reputation may also depend upon their environmental responsibility. Companies can use voluntary environmental responsibility disclosures as an informational signal upon which stakeholders set up their assessments of corporate reputation (Lee and Hutchison, 2005). For instance, when a chemical company receives criticism from stakeholders because it has released toxic substances, the company can deflect the sceptical stakeholders by expressing commitment to the environment (e.g. by equipping its factory with environmentally superior facilities). In this way, environmental reputation can be considered as a signal that managers send to prospective investors with the aim of limiting the problems of information asymmetry (Bansal and Clelland, 2004; Toms, 2002). Moreover, in the case of companies pursuing competition-eliminating strategies (as in the case of 'Raising Rivals' Costs theory'), eco-

innovativeness contributes to building up a stock of ‘reputational capital’ to differentiate the company from the competitors and to increase their costs (Elsayed, 2006; McWilliams et al., 2002).

A survey from the UK Department for Environment, Food, and Rural Affairs (2001) reveals that large companies tend to invest in environmental protection in order to maintain their reputation in the market. Welford (1997) argues that environmental rhetoric coming from businesses represents ill-concealed attempts to control the direction, if not the content of the debate on environment and sustainability. Despite such suspicions regarding the motives underlying companies’ environmental actions and pronouncements, there is evidence that investors exhibit a more than passing interest in companies’ environmental disclosures (Epstein and Freedman, 1994; Firth, 1984).

The significant growth in ethical investment funds suggests that investors are not interested exclusively in the purely financial appraisal of their investments when the environmental (along with the social and ethical) implications of the investments are made apparent (Murray et al., 2006). Similarly, financial analysts and rating agencies are increasingly incorporating environmental considerations in their risk assessments, using companies’ good environmental practices as a proxy for good management. Some investment funds have been established specifically to finance companies that have a sound environmental strategy (OECD, 2007), making environmental disclosures a direct input to ethical investors’ decisions.

In this framework, eco-innovating companies can potentially attract more investors due to the lower perceived compliance costs and liabilities (Wahba, 2008; Branco and Rodrigues, 2008; Konar and Cohen, 2001). Cox et al. (2004) and Graves and Waddock (1994) show that institutional investors invest in companies that have a good environmental reputation. White (1996) finds that investors in companies that achieve an above-average environmental reputation gain risk-adjusted returns greater than other investors have in the overall market. Moreover, Klassen and McLaughlin (1996) find evidence that public announcements of environmental awards have a positive impact on the

market valuation of companies and that a significant negative influence generally follows environmental crises. In recent years, leading providers of equity indexes (e.g. FTSE International in the UK) have launched families of indexes specifically targeted to a socially responsible investment community with the aim of helping investors track the performance of ‘green stocks’. Such influential stock market institutions recognise the possibility of a positive relationship between good environmental results and superior share price performance. Companies selected for these indexes are required to demonstrate that they meet certain minimum standards of environmental performance (Labatt and White, 2002).

Similarly, the development of market-based solutions for environmental problems has begun to play a part in the evolution of the financial services sector. Such environmental financial products must satisfy two different criteria: firstly, they must establish their niche in the marketplace; secondly, they must meet the environmental objectives that they were designed to address. It is worth noting that environmental risks faced by borrowers are important considerations also in bank-lending decisions. Many banks have written policies setting out how environmental factors should be considered in their lending and project finance decisions. A survey conducted by Ganzi and Tanner (1997) suggests that at least half the banks in Europe and North America have some form of assessment of environmental factors built into their credit approval for commercial loans. Finally, some authors (for instance, Brammer and Pavelin, 2004) argue that the reputational payoffs of engaging in environmentally responsible activities are contingent upon the sectors where companies operate, particularly in the environmentally visible ones.

3.4 Determinants of FC

The availability of funds and the existence of FC has been in part analysed in the previous section on companies' financial decisions and capital instruments. However, literature on capital structure is more focused on the analysis of the optimal capital structure of companies than on the availability of financial means. In the last decades, another strand of literature has specifically investigated the determinants of FC, becoming an important field in finance literature. Carreira and Silva (2010) have provided a comprehensive survey about the recent works on this topic showing that the main determinants of FC are represented by differences in: (1) company size, (2) company age, (3) sectoral system of innovation, and (4) national system of innovation.

Company size and FC

SMEs are relatively more financially constrained than larger companies since the availability of their internally generated funds can be more limited, they may lack assets to use as collateral, and they can face more severe problems of asymmetric information (Angelini and Generale, 2005; Gaiotti and Generale, 2002). Consequently, SMEs may be unable to raise external funding to innovate or they can raise them at higher costs. Many studies provide evidence of a negative correlation between size and the degree to which companies do not receive the desired funds (Canepa and Stoneman, 2008; Vos et al., 2007; Beck and Demirguc-Kunt, 2006; Egeln and Licht, 1997).

Company age and FC

Not only company size, but also company age affects the degree of FC. Start-ups and younger enterprises have a shorter history and therefore face more difficulties than older companies in signalling the quality of their investment projects to perspective investors. Furthermore, they are limited in generating cash flow and this makes their constraints additionally tight. The negative correlation between companies age and degree of FC is confirmed by a number of empirical studies, such as Hyytinen and Pajarinen (2008), Vos et al. (2007), and Westhead and Storey (1997).

Sectoral system of innovation and FC

Differences across industries in terms of FC may also exist. According to the Sectoral System of Innovation's (SSI) viewpoint, agents, relationships among actors, and institutions of a sector all exert a major and profound influence on the differences in innovation across sectors (Malerba, 2004b). In their eco-innovative effort, companies interact with other enterprises as well as with non-enterprise organisations, such as financial institutions. Each sector generally relies on a set of prevalent financial institutions, such as public financial support rather than capital markets and bank loans (Malerba, 2004a). Moreover, more profitable industries need less external funding than less profitable sectors. Similarly, riskier industries may face additional difficulties to raise funding from outside simply because of the risk factor. At the same time, information asymmetries may be greater in newer industries where innovation is more likely to be of a sort that has not been undertaken elsewhere before and where it may be tricky to observe the systematic risk of new investment projects, as in the case of 'green' industries. Thus, in newer industries, companies may face stronger constraints in their attempts to raise external funding for innovation in terms of cost and their availability.

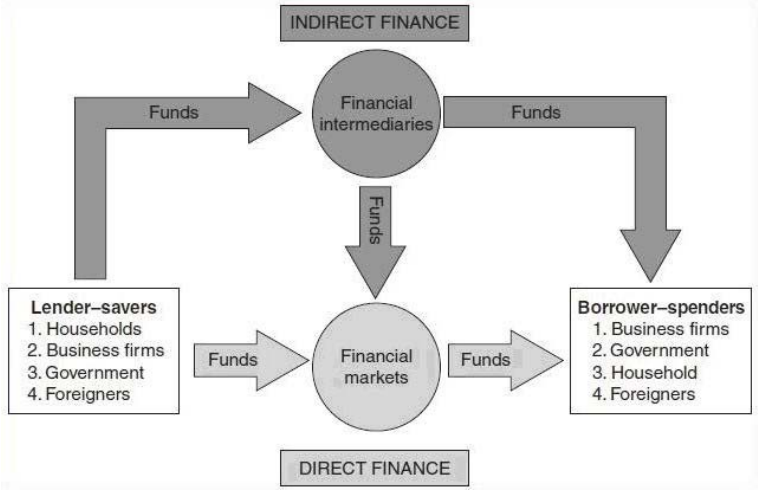
National system of innovation and FC

Finally, according to literature on the National Systems of Innovation (NSI), the structures of innovative activities, their institutional determinants, and economic effects are generally nation-specific, since they are associated with the assumption of historical uniqueness (Balzat and Pyka, 2006). A NSI can be considered as a '*network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies*' (Freeman, 1987). Countries differ in a number of dimensions (e.g. institutional framework, knowledge base, openness, financial environment, etc.), which represent key-elements to define a NSI model (Maskell et al., 1998). Differences in NSI across countries may lead companies to be differently financially constrained, because of different taxes and subsidy regimes, completeness of financial markets, legal environment regarding bankruptcy, government intervention, etc. (Canepa and Stoneman, 2003).

3.4.1 The role of the FS

In the framework of the NSI, differences in financial systems are particularly valuable to investigate the extent to which companies are financially constrained. The Financial System (henceforth FS) consists of all financial intermediaries, financial markets, and their relationship with respect to the flow of funds to and from households, governments, companies, and foreigners, as well as the financial infrastructure. Its main task is to channel funds from sectors that have a surplus of funds to sectors that have a shortage of funds by transforming household savings into funds available for investment by companies. This can occur via financial markets (direct finance) or via financial intermediaries (indirect finance) (Figure 8).

Figure 8 Working of the FS



(**Source**: de Haan et al., 2009)

Through its intermediation role, the FS provides a number of universal tasks, such as:

- A mechanism for pooling funds so that large-scale projects can be financed beyond the capability of individual savers, and so that short-term budget constraints can be removed;
- The supply of a wide range of assets and liabilities with different characteristics to satisfy possible consumers' portfolio preferences and to transfer financial resources over time, space, and agents;

- The creation of risk-sharing facilities to enable agents to manage uncertainty and control risk: the FS engages in asset transformation through financial companies having assets and liabilities with different characteristics that, in the process, enable risks to be shifted to those who are more willing and able to accept them;
- Provision of a payment system and of a range of specialist financial services, such as insurance, fund management, etc.;
- Incentives for the efficient allocation of resources within the economy through price signals such as interest rates and asset prices in primary and secondary markets;
- Dealing with problems of asymmetric information since financial markets and intermediaries reduce the costs of acquiring and processing information about investment projects as well as mitigating the costs of monitoring borrowers. It is worth noting that this task is particularly relevant for FC since, as discussed in section 3.3.2, the existence of asymmetric information helps to explain the existence of financially constrained companies.

Although tasks above (including the dealing with asymmetric information) are universal, the way they are performed by the FSs can vary largely across countries (Llewellyn, 2004; Freixas and Rochet, 1999; Merton, 1995) with the consequence that the financial architecture of a country can have a significant impact upon the innovative activity of companies. To this end, finance literature has identified two main prototypes of FSs, according to the relative importance of banks and markets for corporate financing, i.e. (1) the bank-based systems (BBSs) where the main route for moving funds from lenders to borrowers is mainly the indirect finance and (2) market-based (or stock exchange-based) systems (MBSs) where funds are channelled mainly via financial markets. Literature has primarily identified US and Germany as typical MBSs and BBSs, respectively, because of the significant role in allocating resources played by financial markets in the US and by banks in Germany. Table 8 summarises the structural differences between the two typologies of FS. In the two systems, markets and banks play different roles regarding information production, capital formation, risk sharing, and monitoring. Of particular importance for the classification between BBSs and MBSs, is the relative effectiveness with which

banks and markets execute the informational function (Tadesse, 2006). In MBSs, information about investment opportunities of companies is produced by means of prices formed in financial markets through investor trading. BBSs information, however, comes from projects' evaluation for loan financing. By moving money from a surplus sector (savers) to a deficit sector (borrowers, i.e. companies and private customers), banks examine the financial performance and prospects of the borrower, taking into account all possible factors that can contribute to the loan repayment. In this way, they collect a large amount of information about companies (O'Connor, 2000).

Table 8 Structural differences between MBSs and BBSs

Type of system	**BBSs**	**MBSs**
Financial markets	Small, less liquid	Large, highly liquid
Share of companies listed on stock exchange	Small	Large
Risk-sharing	Banks: intertemporal	Market: cross-sectional
Ownership and control	Concentrate	Dispersed
Way of influence	Voice	Exit
Market of corporate control	Hostile takeover rare	Hostile takeover frequent
Dominant agency conflict	Controlling vs. minority shareholders	Shareholders vs. management
Role of banks in external finance	Very large	Small
Debt/equity ratio	High	Low

(**Source**: adapted form Hölzl, 2003)

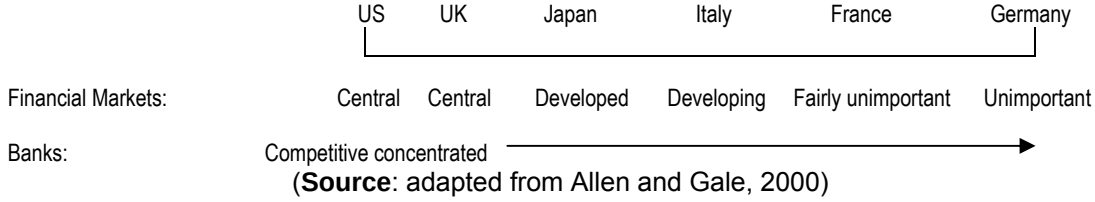
In this framework, a number of opposing arguments have been proposed about which typology of FS (whether BBSs or MBSs) deals better with asymmetric information problems. For instance:

- In banks, the decision to invest in an innovative project is generally delegated to a bank manager. The assessment of new projects is often difficult since little information is available about their potential returns. Sometimes, the information itself may be difficult to judge without some expertise. In the case of a diversity of opinion between investors and manager, the investors may be unwilling to provide funds. Consequently BBS may result in underfunding innovative projects while MBS may allocate funds to a project even if some of the investors think that the project should not be financed (Allen and Gale, 1999);
- Being companies' creditors, banks should have an inherent bias toward prudence. Therefore, BBS could be less effective than MBS in gathering information in new and uncertain markets (Levine, 2002);

- BBS may generate a higher cost of capital for companies due to bank monopoly power and conservatism (Morck and Nakamura, 1999);
- In contrast, banks can retrieve much information thanks to long-running relationships with companies. For example, the bank can learn about companies' sales by monitoring the cash flowing through its checking account. Therefore, enterprises in BBS may benefit from such long-term relationships in the form of access to credit at lower prices than in MBS (Hoshi et al, 1991);
- Unlike MBS, in the BBS the acquisition of information can be economised since only the bank manager needs to be informed about a project (Allen and Gale, 1999). Moreover, long running relations between banks and companies makes BBS work better than MBS for those innovative projects that require financing in several stages as the project develops (Stulz, 2000).

However, the level of complexity of the FSs across the world seems to lag well behind the classification employed so far in the literature between BBSs and MBSs. As reported in Figure 9, the FSs in the major industrial countries fall in between the two polar extremes represented by US and Germany. In particular, in the UK, financial markets have a long history and play a central role, but in contrast with the US, the domestic banking industry is highly concentrated. In Japan, financial markets are particularly sophisticated, although the banking system plays a dominant role in allocating resources. In France, the banks traditionally dominate and markets are unimportant for the corporate sector, but, unlike Germany, the government directly controls the major banks and the other financial institutions. In Italy, the FS is neither BBS nor MBS although it is bank-centred. During the 1990s, the country exhibited a rapid growth of market-based activities and the corresponding decline in the relative importance of traditional bank instruments, although this did not coincide with a reduction in the role of banks, which still play a dominant role.

Figure 9 Overview of FSs in US, UK, Japan, France, and Germany.



(**Source**: adapted from Allen and Gale, 2000)

With the aim of capturing the variety of possible FS configurations, the next section proposes an evolutionary approach to the analysis of FSs, which considers the financial architecture of a country as a complex system where being more bank-oriented or market-oriented represents a possible, although not unique, dimension of FSs.

3.4.1.1 An evolutionary approach to the analysis of the FS

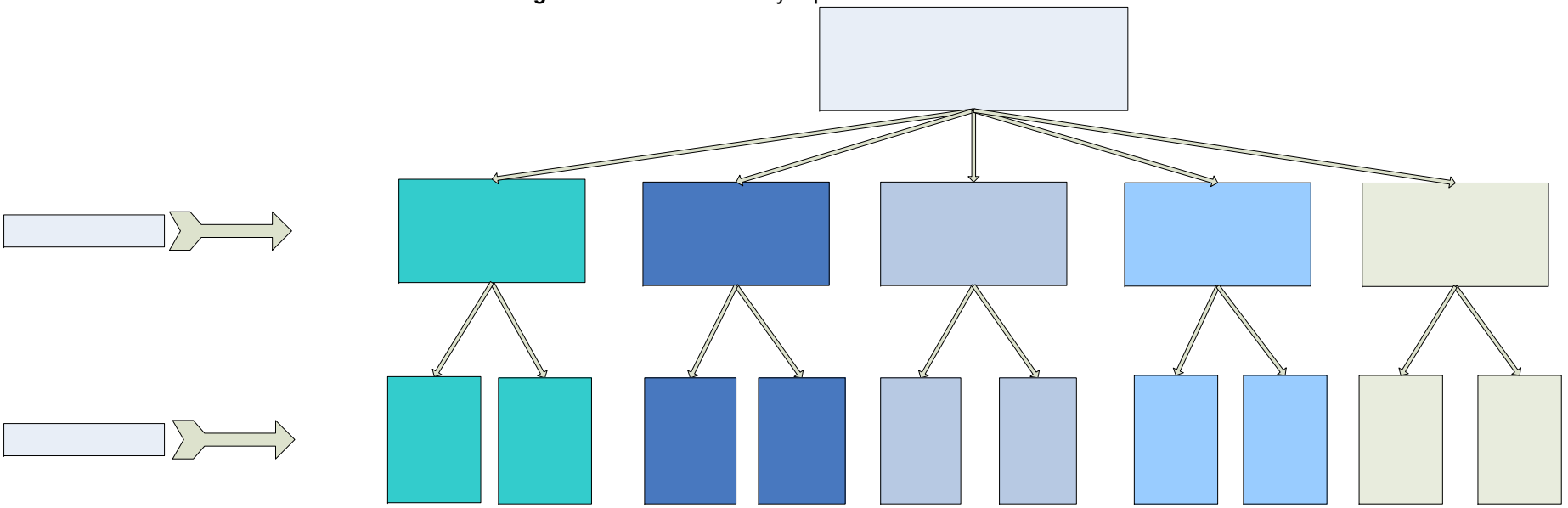
From an evolutionary viewpoint, the FS can be viewed as a complex institution with high interdependence parameters governing the transfer of information, the framework of incentives, and the resource allocation mechanism. In particular, following the works of Hölzl (2003) and Hackethal and Schmidt (2000), the FS can be considered as an ordered set of components that work interdependently with each other and that, in turn, represent a complex system. Such components are:

1. The *patterns of industrial finance*, i.e. the way companies finance their investments. Given the many regularities existing within countries, it is possible to define some nationally specific patterns of industrial finance that represent an important part of the FS in the countries;
2. The *corporate governance system*, i.e. the totality of the institutional and organisational mechanisms and corresponding decision making to resolve conflicts of interest between the different groups that have a stake in a company;
3. The *financial sector*, i.e. the set of financial markets and institutions (banks, insurance companies, etc.), which is defined by the importance of capital markets, the prevalence of universal or specialised banks, and the relative role played by non-bank financial institutions; and

4. The *predominant system of business coordination and organisation*, i.e. the prevailing corporate structures, relationships between companies, employers and strategies, etc.

The above components can be broadened to include the *legal framework*, which represents the system of laws that protect shareholders and creditors in different countries (Figure 10).

Figure 10 The evolutionary representation of the FS



(**Source**: own elaboration based on Hölzl, 2003, and Hackethal and Schmidt, 2000)

ELEMENTS

The patterns of industrial finance

The patterns of industrial finance are given by the main routes through which funds are moved from lenders to borrowers. As argued in the previous section, it is possible to identify bank-oriented systems *versus* market-oriented systems.

The corporate governance system

Since the financial needs of companies are closely connected to their control characteristics, there is a strong relationship between *the patterns of industrial finance* of a country and its *corporate governance system*, i.e. between the way companies finance their investments and the system by which they are controlled, directed, and made accountable to shareholders and stakeholders (Tylecote and Ramirez, 2006). Generally, the national systems of corporate governance can be classified as:

- 'Outsider-dominated' systems (ODS), typical of economies with a low concentration of equity ownership and where shareholders generally do not seek control (such as those of US and UK);
- 'Insider-dominated' systems (IDS), typical of economies with high concentration of equity ownership and where larger blocks are generally held for control (such as those of the Continental European and the East Asian countries).

Consequently, the insider-outsider distinction fits well into the classification of the pattern of industrial finance between market-oriented systems and bank-oriented systems, the outsider economies being generally more market-oriented, and the insider ones more bank-oriented, with the banks that are merely one category of insider, alongside with family owners, government and cross-holding companies. Table 9 reports the main characteristics of the two types of corporate governance systems.

Table 9 Main characteristics of ODS and IDS of corporate governance

	ODS	IDS
Share of control-oriented finance	Low	High
Financial markets	Large, highly liquid	Small, less liquid
Share of companies listed on exchange	Large	Small
Ownership of debt and equity	Dispersed	Concentrated
Investor orientation	Portfolio-oriented	Control-oriented
Use if mechanism for separating control and capital base	Limited (often by regulation)	Frequent
Dominant agency conflict	Shareholders vs. management	Controlling vs. minority shareholders
Role of board of director	Important	Limited
Role of hostile take-overs	Potentially important	Very limited

(**Source**: adapted from Berglof, 1997)

The financial sector

The financial sector is the set of financial markets and institutions, such as banks and other financial intermediaries. Financial markets are markets where individuals issue and trade securities: they aim at facilitating mutually beneficial intertemporal exchanges and at promoting exchanges by organising trading in a variety of financial securities. Thus, a system of financial markets is economically efficient if it allocates resources so that there are no further opportunities or mutually beneficial exchanges. Specifically, financial markets perform the following tasks:

- Price discovery, by enabling participants to find out the prices at which trades can be agreed upon (pre-trading phase);
- Trading mechanism, by providing a mechanism to facilitate agreements, helping economic agents who want to sell to communicate with economic agents who want to buy (trading phase); and
- Clearing and settlement arrangements, by ensuring that the terms of each agreement are honoured (post-trading phase).

Financial intermediaries are economic agents specialised in the activities of buying and selling financial contracts and securities (Freixas and Rochet, 1999). Banks are key players among intermediaries since they provide liquidity to other financial institutions as well as to companies and households. Contemporary banking theory classifies banking functions into four main categories: (1) offering access to a payment system, (2) transforming assets, (3) managing risk, and (4) processing information and monitoring borrowers. In particular, banks play a significant role in managing some of the problems resulting from imperfect information on borrowers, since they can screen the different

demands for loans and monitor the projects, thus limiting the risk that the borrower implements a project different from the one initially established. Asymmetric information lies at the core of banking: banks monitor borrowers *ex ante* by screening projects (adverse selection), during the project by preventing opportunistic behaviour of the borrowers (moral hazard), and *ex post* by auditing borrowers who fail to meet their contractual obligations (costly state verification). Diamond (1984) argues that it is efficient to delegate monitoring to a bank if three conditions are met: 1) they develop economies of scale in monitoring by financing many investment projects; 2) the capacity of individual lenders is small compared to the size of many investment projects, so that each project needs several lenders who would then need to monitor the borrowers; and 3) the costs of delegating monitoring to banks are small. Alternatively, lenders may delegate monitoring to the credit-rating agencies that measure the companies' creditworthiness by assigning credit ratings to companies that issue debt obligations.

The predominant system of business coordination and organisation

The prevailing corporate structures, relationships between companies, employers and employees and strategies, etc., represent an important element of the FSs. Companies can be considered as actors seeking to develop and exploit core competencies or dynamic capabilities, i.e. capacities for producing and distributing goods and services profitably but, in doing so, it is critical that the quality of their relationships with internal actors (e.g. employees) and external actors (e.g. suppliers, customers, stakeholders, trade unions, governments) remains intact. In the presence of hidden action and hidden information problems, these relationships become particularly complicated. Thus, since companies' capabilities are mainly relational, and since companies face several coordination problems, their success depends substantially on their ability to coordinate effectively with a wide range of actors. The Varieties of Capitalism (VoC) approach/literature considers many important institutional structures (e.g. the systems of corporate governance) as depending upon the presence of regulatory regimes that are the preserve of the nation-state. This literature focuses on the strategic interactions, which are central to economic agents' behaviour, by placing companies at the core of the analysis. In this

framework, the sphere of *corporate governance* to which companies turn for access to finance and in which investors seek assurances of returns on their investments, represents a typical example of companies' coordination problems that affect the availability of finance for innovation projects. In particular, in the Liberal Market Economies (LMEs) companies rely primarily on formal contracts and highly competitive markets to organise their relationships with finance suppliers. In contrast, in the Coordinated Market Economies (CMEs), companies coordinate their activities mainly according to non-market relationships.

In LMEs, the actors generally adjust their willingness to supply and demand investments on the grounds of the marginal calculations employed by neoclassical economists, making market institutions a highly effective means for coordinating economic actors. With CMEs, however, companies depend primarily upon non-market relationships with other actors and, consequently, on incomplete contracting, network monitoring based on the exchange of private information inside networks, and more reliance on collaborative, as opposed to competitive, relationships to build the competencies of the company (Hall and Soskice, 2001).

In light of this, institutions (i.e. the set of rules, formal and/or informal, that actors follow for normative, cognitive, or material reasons) hold a strategic role in providing support for the development of relationships among companies and in solving their coordination problems. In particular, in LMEs, markets are the main institutions that support companies' relationships, due to high levels of competition and by means of the legal system that sustains formal contracting. Companies in CMEs coordinate their activities with the support of institutions designed to foster information sharing and collaborations, such as business and/or employer associations, trade unions, extensive networks of cross-shareholding, legal/regulatory systems, etc.. These institutions provide capacities for the *exchange of information* across actors, the *monitoring* of behaviour, and the *sanctioning* of defection from cooperative endeavour. Therefore, they contribute to reducing the uncertainty of actors in regard to the behaviour of other economic actors, allowing them to make credible

commitments to each other. Some studies on sectoral specialisation and technological development across market economies (Casper and Whitley, 2004: Casper, 2000) show that contrasting patterns of technical change can be explained by the different institutional frameworks that have established in distinct types of economy. In particular, it seems that LMEs encourage companies to develop effective innovative competences in industries dominated by rapidly emerging technologies, whereas CMEs foster long-term and incremental innovation strategies, inhibiting more radical innovation paths.

Following the classification proposed by the corporate governance literature between 'shareholder models' (where the maximisation of shareholder value is the most important aim of companies and only shareholders can enjoy strong links with top management) and 'stakeholder models' (where the interests of companies' stakeholders are taken into account in management decision-making), the difference between CMEs and LMEs provides a broader institutional context within which stakeholder and shareholder models of governance can be analysed. Indeed, CMEs (where 'non-market' institutions allow for inter-company coordination and regulate the interaction between owners and managers, employees and companies, and among top managers) are generally characterised by stakeholder models of corporate governance, since a company's stakeholders enjoy a strong formal 'voice' in decision-making through representation on company boards. By contrast, LMEs (where markets play a significant role by influencing inter-company relationships and by regulating the interactions between actors) are generally characterised by a shareholder model of governance because of the weak role of stakeholders compared to that of shareholders in the company's decision-making process (Vitols, 2001).

The legal framework

Although historically financial activities have taken place without an effective legal system or within legal systems that did not play any significant role, nowadays FSs require complex legal systems in order to ensure efficiency and, above all, to codify the policy orientations and values by which that efficiency can be judged (Greif, 2000). Furthermore, the need to encourage the

identification and dissemination of information and to guarantee the protection of trust, the prevention of conflicts of interest, frauds, and systemic crises, justifies a special legislation for finance (Visentini and Musolino, 2008). Despite the fact that laws protecting investors differ widely across countries, it is possible to identify two main traditions in commercial law: The first is the common law tradition, which originated in England and characterises the Anglo-Saxon economies. The second is the civil law tradition, which is particularly spread across continental Europe. According to the literature (Djankov et al., 2002; Mattei, 2000; Glendon et al., 1999; Katz, 1986), common-law systems are more effective than civil-law systems in resolving conflicts, since judges have the possibility to create the law when the codes do not address a specific problem.

In various influential works, La Porta et al. (2000, 1998, and 1997) compare a number of FSs on the ground of their legal frameworks. The authors argue that distinguishing countries by the efficiency of their legal system in supporting financial transactions is more useful than distinguishing them by their financial structure, since the legal systems, which protect outside investors, facilitate external financing, new company formation, and efficient capital allocation. Moreover, they suggest that the civil law systems provide investors with weaker legal rights than common law systems. The studies by Beck and Levine (2002), Carlin and Mayer (2000), and Demirgüç-Kunt and Maksimovic (1998a, 1998b) confirm the 'law and finance' view of La Porta et al., by pointing out that the financial structure *per se* does not explain important industrial performance, while the legal environment is critically valuable for industry growth and for fostering an efficient capital allocation.

3.4.1.2 The complexity of the FS

To understand the potential of the evolutionary analysis of the FS discussed in the previous sections, it can be useful to turn to Kauffman's (1993) NK model of complex biological organisms as analysed by Hölzl (2003). This model simulates the evolution of complex systems by a set of *N* elements that can take on *Ai* possible values. The number of all possible strings among system

elements, i.e. 'the possibility space of a system' - is equal to A_i^N. This number represents *all possible system types that the different combinations of elements contribute to*. Therefore, for a binary FS consisting of five elements (N = 5; A_i = 2) the possibility space is equal to 2^5 = 32. Moreover, if *K* denotes how interdependent the characteristics are in determining this contribution, two extreme cases are possible: on the one hand, *K* can be equal to *0* meaning that the level of complexity is minimum, i.e. each element contribution is independent of all others in determining the type. On the other, *K* can be equal to *N-1* meaning that the level of complexity is maximised, i.e. each element contribution depends on all other elements. Following the NK model, it is therefore possible to identify many different typologies of FSs, despite the one-dimensional dichotomy between MBSs and BBSs traditionally employed in the financial literature, which appears to be too simplistic to depict the real state world and does not suit the characteristics of many countries (Hölzl, 2003).

Indeed, a number of FSs across the world are neither MBS nor BBS, and US, UK, Japan, and Germany seem to represent only an exception. Similarly, BBSs and MBSs can coexist in the same country, although with a different role and importance. It is worth noting that the five elements that characterise the FSs (i.e. patterns of industrial finance, corporate governance system, financial sector, system of business coordination and organisation, and legal framework) may be highly correlated with each other, with the consequence that *K* can also assume quite high values, i.e. high levels of complexity. For instance, bank-oriented systems find their optimal complement in laws that do not allow hostile takeovers and consequently foster stable and concentrated ownerships. From this viewpoint, in CMEs, banks monitor companies' investments by sitting in on their boards, thus providing capital according to the direct knowledge of industrial strategies. Consequently, the stock market is generally underdeveloped in CMEs because even listed companies tend to seek funds from banks and not from equities (Simoni, 2011). By contrast, in LMEs, the law prevents banks from owning shares in non-financial companies and minority shareholders rights are generally well protected with the consequence that ownership is diffused through highly developed stock markets. Ergungor (2004) argues that financial intermediaries emerge spontaneously in civil-law countries,

where the literal interpretation of contract language by the courts makes the writing of one-time bilateral contracts problematic. In this way, financial intermediaries arise as institutions that can resolve conflicts and enforce contracts without court intervention. By contrast, the typical discretion of judges in interpreting contract language in common-law systems reduces the risk of contracting costs, thus favouring the development of financial markets. In other words MBSs tend to be generally outsider-dominated, with well performing financial markets operating in liberal market economies, and within a common law framework. While bank-oriented systems are generally insider-dominated, with well performing financial intermediates operating in coordinated market economies, and characterised by a civil law system (Malerba, 2004b: 477; Demirgüç-Kunt and Levine, 2001: 83; La Porta et al., 1997).

3.5 Summary of the chapter

The main points emerging from the chapter can be summarised as follows:

- EIs are driven by a mix of different drivers that originate from inside and outside the company. From inside, the degree of eco-innovativeness is driven mainly by a company's size and cost-saving needs. From outside, the most significant driving forces of EIs are the environmental policy, the market structure, and the demand for green goods and services. In this framework, the lack of former investigations about the role of companies' financial resources as possible drivers or barriers to their eco-innovative decisions emerges.

- Eco-innovative investments can be financed by recurring to internal or external funds. Financial markets and intermediaries are paying an increased attention towards eco-innovative projects by providing new options of external private funds to eco-innovative enterprises and by integrating environmental criteria into the lending process (green finance).

- Finance literature suggests that companies exhibit a strict ordering of finance, by using internal financing first, then debt, and only when such

options are exhausted, is equity considered. The preference for internal rather than external financing is explained by the fact that these two sources of financing are not perfect substitutes due to the existence of market imperfections ('hidden information' and 'hidden action' problems). This can determine the companies' risk of being financially constrained. Within the external financing, the preference for debts rather than for equity is explained based on different theories, such as the tax-based and agency cost theories and the asymmetric information theory.

- A possible way for eco-innovative companies to reduce asymmetric information could be represented by environmental reputation. Indeed, companies with a good environmental reputation can potentially improve relations with external actors, such as investors and bankers, due to the lower perceived compliance costs and liabilities.

- The main determinants of financial constraints are represented by differences in company size, company age, and sectoral and national systems of innovation. In particular, in the framework of the national system of innovation, differences in financial systems are particularly valuable to investigate the extent to which companies are financially constrained.

- The level of complexity of the financial systems across the world lags well behind the traditional classification employed so far in the literature between bank-based and marked-based systems. In contrast, the financial system can be viewed as a as an ordered set of components that work interdependently with each other and that, in turn, represent a complex system. Such components are the *patterns of industrial finance*, the *corporate governance system*, the *financial sector*, the *predominant system of business coordination and organisation*, and the *legal framework*. In this way, it is possible to identify many different typologies of financial systems, despite the one-dimensional dichotomy between bank-based and marked-based systems traditionally employed in the financial literature, which does not suit the characteristics of many countries.

4. THE THEORETICAL MODEL

4.1 Introduction

The present chapter deals with the theoretical model developed in this thesis, by integrating the findings reported in Chapters 2 and 3 in a comprehensive framework. The chapter presents a descriptive model based on the well-established theoretical setting of the evolutionary theory, trying to capture the complexity of EIs' contribution to the transition from the current (unsustainable) regime to a green economy where EIs become the market standard and environmental issues are fully integrated into all economic processes. While moving towards a sustainable regime, green competitiveness becomes increasingly important and influences the selection of suppliers, customers, learning partners, employees, and financial institutes, to name a few. Once the sustainability transition is achieved, companies and economic sectors should exhibit routinized environmental strategies and high environmental standard profiles, consumers should exhibit routinized consideration of green demand, and knowledge institutions should exhibit routinized green research and education. In particular, the model tries to identify the role played by FC in hindering the eco-innovativeness of companies and, therefore, the transition process towards more sustainable regimes. The chapter is organised as follows: Section 4.2 describes a starting model used to describe the process of socio-technical transitions. Section 4.3 augments the starting model by assessing the contribution of EIs to the *sustainability* of socio-technical transitions. Section 4.4 completes the theoretical framework by adding FC into the model. Finally, section 4.5 concludes by formulating the research hypotheses.

4.2 The starting model

The model presented in this chapter stems from the Multi-Level Perspective (MLP) first introduced by Rip and Kemp (1998) and then refined by Geels (2002), which has been briefly touched on in section 2.4.1. The MLP has

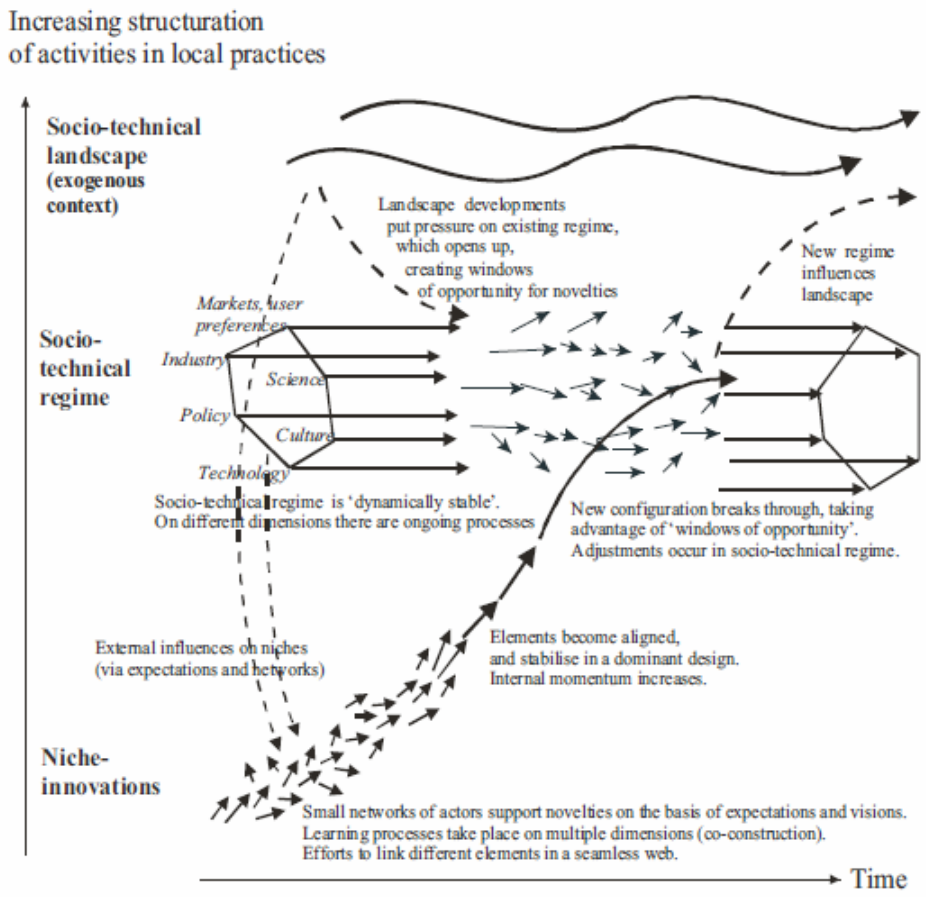
emerged as a dominant approach for investigating shifts in social, economic and technological arrangements since it allows to investigate radical technological changes and their diffusion by emphasizing the role of social group interconnections and dynamics in system change (McMeekin and Southerton, 2012; Papachristos, 2011). In particular, the model focuses upon sociotechnical systems, i.e. clusters of aligned elements, such as technical artefacts, knowledge, regulation, markets, rules, cultural meaning, etc., allowing to capture the complexity of interlinked relationships that affect sociotechnical transition processes as well as their underlying driving forces (Kern, 2012). More specifically, the model consists of three linked levels: socio-technical regime, socio-technical landscape, and niche-innovations (Söderholm & Elin Wihlborg, 2015).

- The *socio-technical regime* represents the *meso-level unit of analysis* and can be defined as a relatively stable configuration of institutions, techniques and artefacts, as well as rules, practices and multi-actor networks that determine the 'normal' development and use of technologies (Berkhout et al., 2004; Rip and Kemp, 1998). It involves different social groups (e.g. engineers, scientists, policy makers, users, societal groups, suppliers, etc.), which embed a semi-coherent set of rules and cognitive routines that support the existing systems (Fallde and Eklund, 2015).
- The *niche-innovations level* represents the *micro-level* and consists of protected spaces or 'incubator rooms' (niches) where actors develop and test promising technologies that deviate from existing regimes. Niches aim at enhancing the further development and the rate of application of new technologies and learning about their desirability (Geels and Schot, 2007; Kemp et al, 1998). Despite the fact that niche-innovations may perform poorly in more conventional terms (e.g. in terms of price) they are given the opportunity to be evaluated and to mature through gradual experimentation and learning by niche actors (producers, users, researchers, etc.) (Steinhilber et al., 2013).
- The *socio-technical landscape* represents the *macro-level* of the model and is an external structure or context for interactions of actors where a number of different and heterogeneous forces exert pressure upon the meso-level and the micro-level (i.e. the regime and the niche) (Papachristos, 2014;

Geels, 2002). It includes factors that do not change or that change only slowly (e.g. the climate, cultural values, demographic trends, broad political changes) as well as rapid exogenous shocks (e.g. wars, economic crises, shocks in oil prices) (Van Driel and Schot, 2005).

The relation between the three above-mentioned levels can be explained as follows: The socio-technical regime accounts for the *dynamic* stability of existing technological developments, since it guides the innovative activity by means of incremental innovations along trajectories. The socio-technical landscape consists of slow changing external factors that provide deep-structural *gradients of force,* making some trajectories easier than others. Finally, the niche-innovations level accounts for the development of radical innovations (Geels and Schot, 2007). The three levels are more than ontological descriptions of the reality since they represent '*analytical and heuristic concepts to understand the complex dynamics of sociotechnical change*' (Geels, 2002: 1259). More specifically, a socio-technical transition is the consequence of co-evolutionary dynamics and occurs when pressures from the landscape level couple with sufficiently developed niches (Upham et al., 2014). According to the model, niche-innovations struggle against the existing regime and therefore require changes in the socio-technical regime (e.g. in consumer practices, public policies, etc.) in order to propagate sufficiently to transform existing arrangements. The selection and integration of niche-level innovations by regimes is more than adoption since regime-level actors have to integrate new technologies in their practices, organisations and routines (Slayton and Spinardi, 2016). Eventually, when the sociotechnical landscape exerts *destabilising pressures* on the existing regime (and eventually on the niche), niche-innovations then have the opportunity of emerging and competing with the existing regime, and eventually going into the mainstream markets (Turnheim and Geels, 2012). (Figure 11).

Figure 11 MLP on sociotechnical transitions



(**Source**: Geels, 2011: 28)

Therefore, the ultimate success of a socio-technical transition crucially depends on the following interactions:

1. External-to-the-niche conditions that develop at landscape level and exert *destabilisation pressures* (on the regime and, eventually, on the niche). Such pressures lead to re-configurations during which niche-level innovations can diffuse into the existing regime, and in turn reshape it (Grünewald et al., 2012).
2. Changes in the socio-technical regime, which create windows of opportunity for niche-innovations. A reorientation of regime-level actors is required since they normally defend existing systems and regimes (de Almeida and de Melo, 2016)
3. Sufficiently developed niches where radical innovations have been previously tested before being introduced more widely (Berry et al., 2013).

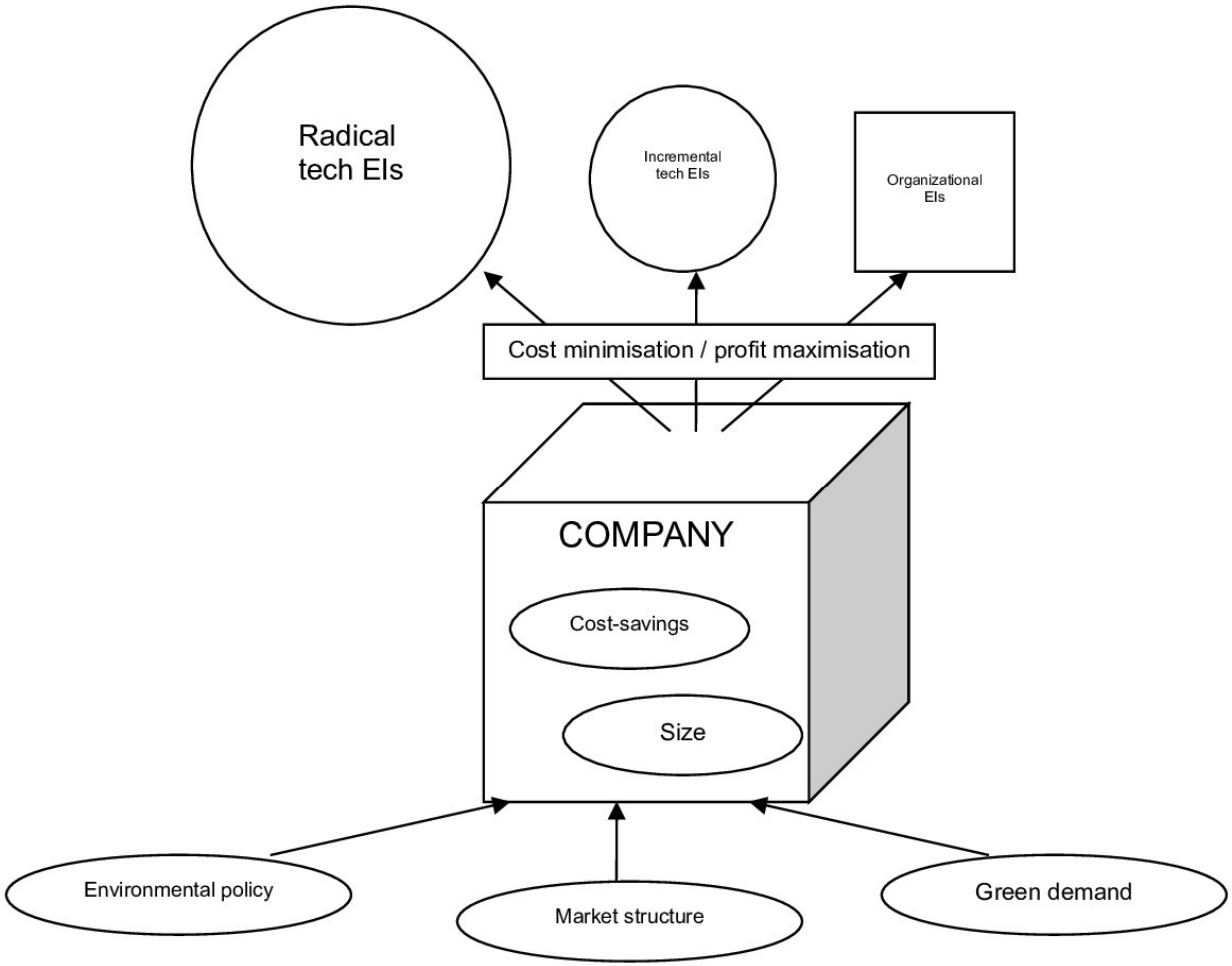
The above conditions do not cause, or unidirectionally drive, the others but they link up with, and reinforce, each other following a process of 'circular causality'. Moreover, the interactions among niche, regime, and landscape occur following several phases, e.g. emergence, take-off, acceleration, and stabilisation (see Geels, 2011, for more details).

4.3 Assessing the contribution of EIs to the starting model

In the framework of the above model, this section moves towards the specific case of *sustainability* transitions, i.e. socio-technical transitions towards more sustainable regimes, by assessing the contribution of EIs to the systemic sustainability changes. There is, indeed, a widespread consensus that EIs represent an enabling factor for the transition towards a green economy (del Rio et al., 2015; Marin et al., 2015). As argued in section 3.2, EIs are driven by a mix of different drivers that exert a certain amount of pressure on companies, thus pushing them to eco-innovate. Drivers originate from inside and outside the company and can interact with each other in a dynamic way (Agan et al., 2013; Horbach et al., 2012). From inside, the degree of eco-innovativeness is driven mainly by a company's size and cost-saving needs. Such factors represent internal preconditions and features of the company, which foster the enterprise's involvement in environmental technological change (Del Rio et al.,

2016; Del Río, 2009: 863). From outside, the most significant driving forces of EIs are the environmental policy, the market structure, and the demand for green goods and services. These external factors exert pressures to which companies respond and represent interaction with other institutional, market, and social actors (Hojnik et al. 2016). (Figure 12).

Figure 12 The most significant EI drivers



Source: own elaboration

When companies are driven to eco-innovate, their innovative output can consist of technological or organisational EIs. Both of them represent a way for enterprises to pursue the traditional business goals of cost minimisation and profit maximisation. On the cost side, EIs allow companies to rationalise the amount of inputs utilised in their production process, thus reducing energy, material, waste treatment costs, etc. (section 3.2.5). Moreover, EIs represent a way to comply with environmental regulations, so that they avoid the risk of incurring high administrative or judicial costs. On the profit side, eco-innovating represents a possible strategy for product differentiation, allowing companies to acquire a competitive advantage against competitors (section 3.2.2). As argued in section 2.2.1, eco-innovating companies cannot be defined exclusively on the basis of their environmental motivation, since the environmental performance of their innovative effort must also be considered, by analysing whether the innovation causes a 'net environmental improvement', i.e. whether it allows preserving or even improving a specific environmental situation.

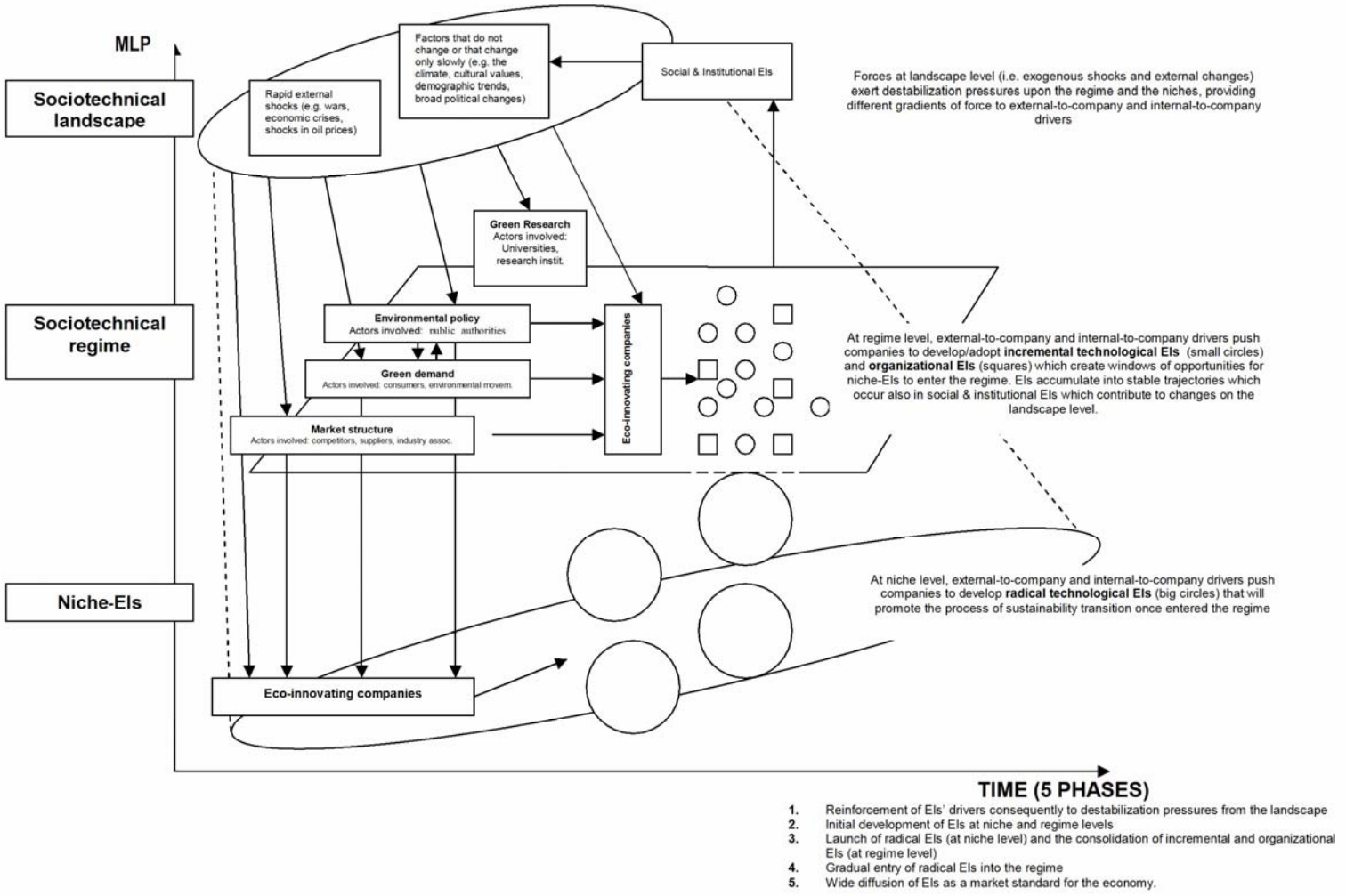
Both technological and organisational EIs contribute significantly to the process of sustainability transitions. In particular, technological EIs can be of two different types, i.e. radical or incremental. Radical EIs focus on departing from existing technology and are characterised by high uncertainty, high risks, and the potential for high returns. Consequently, they are developed at niche level where they have the possibility to be tested and appreciated. In contrast, incremental EIs enhance the environmental performance of established technologies through refinement and improvement. Since they put more attention on current technology rather than on departing from the existing trajectory of technologies, they do not need to be formerly experimented and matured in a protected space (i.e. in the niche) to succeed and thus they enter straight into the regime. At this point, incremental technological EIs along with the contribution of organisational EIs promote part of the changes at the socio-technical regime level, which are necessary for niche EIs to succeed. In other words, drivers of EIs foster the process of sustainability transition:

- At regime level, by driving companies to develop or adopt incremental technological EIs and organisational EIs, thus creating favourable conditions for niche EIs to enter the regime.

- At niche level, by driving companies to develop radical technological EIs that will promote the transition once entering the regime.

It is worth noting that internal-to-company drivers (i.e. company size and cost-saving needs) act within regime and niches according to whether companies operate within the regime (and hence they develop/adopt incremental technological EIs and organisational EIs) or within a niche (and hence whether they develop radical technological EIs). By contrast, external-to-company drivers (i.e. environmental policy, market structure, and demand for green goods and services) are located at regime level although they exert pressures both upon the regime level and the niche level companies. In this framework, external forces at landscape level (e.g. demographic trends, macroeconomic shocks, etc.) exert destabilisation pressures upon the regime and the niches, providing thus different gradients of force to drivers (Figure 13).

Figure 13 EIs, drivers, and sustainability transitions



Source: own elaboration

Similarly to the greening of innovation systems (section 2.4.2), it is possible to identify different phases that characterise the interactions among niche, regime, and landscape that lead to sustainability transitions. The first is the emergence of destabilisation pressures exerted from the landscape providing force to EIs' drivers. The second is the initial development of EIs at niche and regime levels. The third is the launch of radical EIs (at niche level) and the consolidation of incremental and organisational EIs (at regime level). The fourth is the gradual entry of radical EIs into the regime. The fifth is the wide diffusion of EIs as a market standard for the economy. In this framework, the contribution of EIs to the process of sustainability transitions can be assessed by making reference to their environmental performance relative to the current technologies. In other words, the better EIs (both radical and incremental) perform in environmental terms than technologies that are currently employed at regime level, the more they can foster a sustainability transition. However, as already argued in section 2.2.1, such assessment requires an extensive understanding of the contextual relationships of the innovations, since their environmental performance may depend upon their interaction with other factors. In the case of radical EIs, such an assessment can be additionally complex since interactions should be evaluated by taking into account not only the current contextual relationships of EIs at niche level, but also by predicting how the relationship will evolve in the event that the EI should succeed and enter the regime.

4.3.1 Conditions at landscape-level

Forces at landscape-level (i.e. exogenous shocks and external changes) exert a destabilisation pressure upon the regime and the niches. Although on the one hand, they can even reinforce the lock-in of the ongoing regime structures (Geels, 2013), they can also provide different gradients of force to drivers of EIs creating thus favourable conditions for a paradigmatic shift towards new green patterns of consumption and production. For instance, oil shocks can increase the cost-saving needs of companies; the climate change can drive policy makers to implement more stringent environmental regulations in a country; environmental problems at global and local level can increase social awareness for the need for green consumption and production, etc. The adjustments at

regime level fostered by EIs accumulate into stable trajectories, which occur not only in technological and organisational aspects, but also in social and institutional trajectories that are coordinated by different sub-regimes that interpenetrate and co-evolve with the technological ones (Geels, 2011). From the viewpoint of this thesis, such social and institutional dimensions can be defined in terms of 'social' and 'institutional' EIs (section 2.2.2). More specifically, social EIs are changes in lifestyle and consumer behaviour induced by an increased awareness about the environmental concerns. Institutional EIs are the creation of new regimes of environmental governance in terms of local network agencies, international environmental organisations, etc. Both of them contribute to changing the landscape level in a process of circular causality, which makes the interactions among niche, regime, and landscape linked up and reinforced with each other. Social and institutional EIs play a significant role in promoting the process of sustainability transitions by providing the basis for the creation of standards for sustainable development (Urbaniec, 2015). Institutional EIs create the basic conditions to successfully manage the transition process by avoiding the risk that radical technological EIs face a mis-match with existing institutions (Freeman and Perez, 1988). Social EIs raise the management's awareness of the need to integrate environmental considerations in the product's development. Before environmental issues are routinized within companies' strategies, managers decide to eco-innovate mainly to improve the company's image and foster their relation with customers, thus acquiring a competitive advantage towards competitors (section 3.2.3).

4.3.2 Changes in the socio-technical regime

Destabilisation pressures from the sociotechnical landscape can reach different actors and social groups at regime level, such as consumers and environmental movements, universities and research institutes, policy makers, enterprises, industry associations, etc.). In this way, external-to-company and internal-to-company drivers of EIs gain momentum, consequently pushing enterprises *at both regime and niche level* to eco-innovate. In this process, networking and cooperation with universities becomes essential for achieving a sustainability

transitions due to the relevant contribution of the scientific advancements provided by the green research (Cainelli et al, 2012).

At the external-to-company level, environmental policy plays the most significant role in driving enterprises to eco-innovate. As argued in sections 2.3.2 and 3.2.1, the necessity behind implementing environmental policies stems from the need to correct for market failure arising from the 'double externality problem' (in the neoclassical perspective) and to deal with 'system failures' (in the innovation system perspective). In the first case, environmental policy corrects for the undersupplied level of EIs arising from the fact that they combine a benefit for the company or user as well as for the environment. In the second case, since technological EIs can be hindered by existing technologies, which are locked-in because of path dependence, environmental policy drives eco-innovating companies to cope with technological changes, by providing public support for infrastructure, generating incentives for new technologies, and overcoming barriers created by the prevalence of incumbent technology. Regardless of the type of policy instrument adopted, the effectiveness of environmental policies to foster niche EIs is affected by their stringency and predictability (sections 3.2.1.1 and 3.2.1.2). The life span of the preparation as well as the implementation periods of environmental policies contributes to the lock-in of the existing unsustainable regime, delaying the possibility for structural changes to occur. The market demand for green goods and services is another external-to-company driving force pushing enterprises to eco-innovate. The green demand from individual consumers and environmental movements push companies to include environmental attributes in production processes and product design, as well as to acquire quality assurances for environmental management. Indeed, EIs may improve the image and environmental reputation of companies, enabling better relations towards consumers and stakeholders. Finally, different market structures (i.e. whether more power oriented or competitive oriented) can affect companies' eco-innovativeness in two contrasting ways. Firstly, market power regimes drive EIs by allowing eco-innovating companies to appropriate the expected innovation rents by means of patents and market barriers to prevent imitation. Secondly, more competitive markets foster companies to eco-innovate as a way to

differentiate from their competitors and thus remain competitive in the market. In other words, EIs are driven mainly by better appropriability conditions in market power regimes and by differentiating company strategies within competitive markets. Within the market, company suppliers and industry organisations can also drive enterprises to eco-innovate by means of interactions across the chain of production for projects resulting in environmentally friendly products.

At internal-to-company level, company size can significantly affect the level of eco-innovativeness of enterprises. For instance, SMEs could be spurred not to eco-innovate, since they are perceived as less of an environmental risk than large enterprises by media and stakeholders. Moreover, the capacity of companies to eco-innovate largely depends on access to information about the environmental risk of their activities. Consequently, large enterprises have more resources to enhance their ability to possess and process environmental information than SMEs. Finally, companies can be driven to eco-innovate by internal cost-saving needs, since EIs enable companies to reduce energy, material, waste treatment costs, etc.

As argued earlier, the diffusion of EIs at regime level (i.e. incremental technological EIs and organisational EIs) cannot produce a sustainability transition by itself (the existing regime being characterised by a lock-in), but may contribute significantly to creating adjustments in the sociotechnical regime that enable windows of opportunity for niche EIs to enter the regime. Following the classification proposed in section 2.2.2, incremental technological EIs can be considered mainly (although not exclusively) as curative technologies, which repair environmental damages after they have occurred, other than as additive technologies, which are employed to remove contaminants after they have produced but before they are disposed of.[15] Organisational EIs are the incorporation of environmental perspectives and environmental-respectful awareness into companies' strategies and practices and are generally complementary to the adoption of technological EIs at company level.

[15] In contrast, integrated technologies (which prevent environmental damages during the production process and at product level) can represent either incremental or radical EIs according to the specific technology taken into account.

Companies can pursue different environmental strategies, such as a follower, a market-oriented, and an environment-oriented strategy (section 2.2.1). The more companies move from a follower to an environment-oriented strategy, the more they contribute towards promoting a sustainability transition, since the environment becomes an integral element of their corporate strategy. At the same time, the process of sustainability transition fosters the adoption of environment-oriented strategies in companies according to the circularity causality discussed earlier in the section.

4.3.3 Technological EIs and niche-level

Within the niches, radical technological EIs have the possibility of being tested, thus providing the seeds for a systemic sustainable change. The Krozer's model described in section 3.2.1.2 can be opportunely adjusted to model how environmental policy affects the development of radical technological EIs at niche level, providing also a prediction of the estimated time necessary for it to succeed. The model is based on a 'policy cycle' and an 'eco-innovating cycle', which are interlinked with each other. The policy cycle is made up of signalling, preparation, implementation, and evaluation periods. The eco-innovating cycle is composed of technology development, waiting, sales, and maturation periods. At niche level, companies begin to eco-innovate during the signalling period with the aim of anticipating future environmental regulations. At this stage, companies face a major level of uncertainty, since the eco-innovating investments might not produce the expected outcomes. If some positive result is reached, companies begin to promote their EIs and then sell them during the implementation period. EIs will reach their maturity period when and if they enter the regime. Considering that the signalling period can last up to 20 years and that the overall time between the development, experimentation, and sales of EIs can last up to 10 years or more, the possibility that radical technological EIs can enter the regime requires many decades.

When the destabilising pressures create windows of opportunity to niche EIs at regime level, they can enter the regime. However, this can happen only if niches are sufficiently developed. According to the literature on sociotechnical

transitions (Geels, 2011; Schot and Geels, 2008), the development of a technological niche can generally be defined in terms of the following three processes:

1. The expectations of actors about the future development of the niche;
2. The learning process on various dimensions, such as infrastructure requirements, organisational issues, symbolic meanings, etc.; and
3. The number of links among actors, which characterises the social network architecture of the niche.

The expectation level is important to attract attention and resources as well as new actors, especially when the radical technological EIs are still in their early development and their functionality and performance are still unclear. Expectations also provide direction to development by acting as cognitive frames for making choices in the design process. In the case of EIs, the design is based upon the integration of environmental considerations into the development of products, by addressing all their environmental impacts without compromising other criteria like function, quality, cost, appearance, etc. (section 2.2.2). The more environmental aspects are taken into account in the development of radical technological EIs, the more these can contribute to deviating from the existing regime. Upward convergence of expectations requires that an increasing number of actors share the same and common positive view on the future development of the niche (Kemp et al. 1998). It is worth noting that environmental policy contributes not only to driving the development of radical technological EIs at niche level, but also to fostering the development of the entire niche by raising the level of expectations of niche actors.

The achievement of a stable configuration (‘dominant design’) resulting from the alignment of various learning processes is crucial for the niche development (Geels, 2011). It is worth noting that learning can occur both individually (as producers increase their knowledge simply ‘by doing’) and collectively. The latter option implies that companies and other stakeholders involved in the niche share the possessed knowledge (Kemp et al., 1998).

Finally, the number of links among niche actors is effective for niche development when the network is broad, i.e. it includes producers, policy

makers, scientists, and other relevant actors. Moreover, alignment within the network can be fostered through regular interactions between the actors (Lopolito et al., 2011).

4.4 Adding the financial dimension into the model

Along with the assessment of the role of EIs in the sustainability transition process reported in the previous section, the significant contribution of this thesis stems from the integration of the financial dimension into the model. The starting point for the discussion is the recognition that technical trajectories involve not only scientists, public authorities, consumers, suppliers, etc., but also involve finance-related actors, such as banks, investors, VC providers etc. In other words, the transition towards more sustainable regimes is the result of a co-evolution process that involves scientific, political, cultural, market and *financial* dimensions, the last being coordinated by a sub-regime that interpenetrates and co-evolves with the others.

Indeed, as argued in section 3.4.1.1, the FS can be analysed in terms of a complex institution with high interdependence parameters governing the transfer of information, the set up of incentives, and the resource allocation mechanism. In turn, the five components defining the FS (i.e. the patterns of industrial finance, the corporate governance system, the financial sector, the predominant system of business coordination and organisation, and the legal framework), represent complex systems that are slowly co-evolving together over time and that combine in different ways, giving rise to a number of different typologies of FSs.

Moreover, as discussed in section 3.3.2.1, in the absence of capital market frictions the cost of internal and external funds should be the same so that profitable eco-innovating projects should always be funded even if the project cost exceeds internal funds. However, the existence of asymmetric information between companies and prospective investors determines the imperfect substitutability between internal and external financing and the consequent risk for eco-innovating companies to be financially constrained in the case of

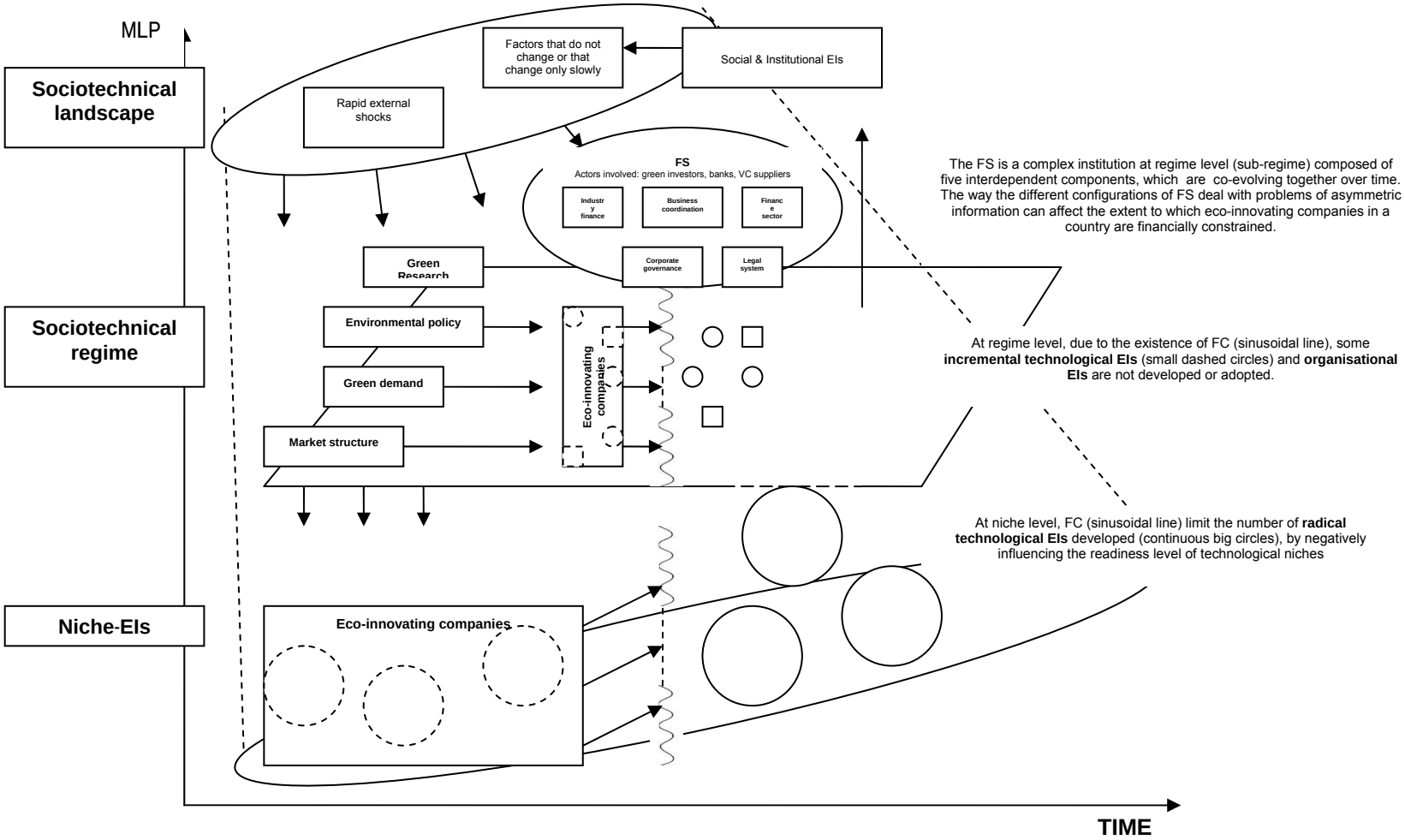
internal funds shortage. In this framework, the way the different configurations of FS deal with problems of asymmetric information can affect the extent to which eco-innovating companies are financially constrained, although it is not possible to predict with certainty which configuration of FS is the most suitable to foster the eco-innovative behaviour of companies.

In the MLP, the existence of FC can affect the possibility for sustainability transitions to occur by means of joint action at two levels:

1. At regime level, since FC may prevent the development or adoption of incremental technological EIs and organisational EIs, effectively hindering the creation of favourable conditions (windows of opportunity) for niche EIs to emerge.
2. At niche level, since FC may hinder the development of radical technological EIs, which can promote the transition.

The inability of eco-innovating companies to fund their desired investment projects therefore represents an obstacle to the alignment process across the sociotechnical regime and niche-EIs, which is necessary for a sustainability transition to take place. Figure 14 extends Figure 13 by adding two barriers into the model, which represent FC at regime and niche levels (sinusoidal lines). When pressures at landscape level push companies at regime and niche levels to eco-innovate, the existence of FC may hinder the degree of eco-innovativeness in the companies, limiting thus the possibility for a systemic change to occur. Some promising technologically radical EIs at niche level (big dashed circles) are not developed and the same happens to some incremental technological EIs (small dashed circles) and organisational EIs (dashed squares) at regime level, which are not developed and/or adopted. This can produce different consequences according to the phase of the sustainability transition. In particular, if FC hinder the initial development of EIs (or their launch or consolidation), the transition towards a more sustainable regime can be permanently jeopardised. By contrast, if FC involve the next phases of transition (i.e. the entry of radical EIs into the regime or the diffusion of EIs as a market standard for the economy), then sustainability transitions are delayed but not necessarily prevented.

Figure 14 The MLP model with the financial dimension



Source: own elaboration

4.5 Implication and derivation of research hypotheses

The theoretical model developed in the previous sections leads directly to the research hypotheses postulated in the present thesis, summarising and integrating the findings from Chapters 2 and 3. As we have seen, a sustainability transition can occur only when pressures from the landscape level exert destabilising pressures on the existing regime in order to create windows of opportunity for niche EIs to emerge. Such pressures allow external-to-company and internal-to-company drivers to gain momentum, thus pushing enterprise to introduce incremental technological EIs and organisational EIs at regime level and radical technological EIs at niche level. Simultaneously, niche level EIs must be sufficiently developed and ready to enter the regime. During the first phases of sustainability transitions, the eco-innovative efforts of companies are aimed mainly at minimising production costs and maximising profits. Only in the last phases of transition (when EIs begin to be widely spread in the system and become a market standard for the economy) do eco-innovating companies exhibit an increase in their proactive behaviour. However, the existence of FC may prevent eco-innovating companies from funding all their desired investments. By impeding the development and diffusion of EIs at both regime and niche levels, FC can in effect hinder the alignment among sociotechnical levels, jeopardising the entire process of a sustainability transition. The above considerations lead to formulating the following two research hypotheses:

H1 The existence of FC hinders regime level companies from engaging in all the eco-innovating projects desired that would otherwise allow niche level EIs to enter the dominant regime.

H2 The existence of FC affects the development of radical EIs at niche level, by negatively influencing the readiness level of technological niches, which is assessed in terms of networking activity among actors, level of knowledge of actors about the organisational and technological niche related aspects, and expectations of actors about the future development of the niche.

5. METHODOLOGY

5.1 Introduction

The present chapter deals with the research methodology employed in this thesis to address the research questions in accordance with the hypotheses derived from the theoretical model presented in Chapter 4. As hypothesised in section 4.4, the existence of FC can hinder the possibility for a sustainability transition to occur by acting at two different levels: Firstly, FC can prevent the creation of favourable conditions at regime level by hampering the development and/or adoption of (incremental) technological EIs and organisational EIs. Secondly, they can hinder the development of (radical) technological EIs at niche level. Coherent with such theoretical framework, the empirical analysis carried out in this thesis was based on the implementation of a survey that employed *ad hoc* designed questionnaires to investigate how FC affect the eco-innovative decisions of companies in regard to the development/adoption of:

1. Incremental technological EIs and organisational EIs at regime level.
2. Radical technological EIs at niche level.

In other words, the thesis carries out two different empirical investigations (i.e. one at regime level and the other at niche level) that, although independent of each other, allow on the whole answering the MRQ and the SRQs.

Moreover, since the extent to which companies are financially constrained can be influenced by the characteristics of a country's FS, the type of industry, and the company size and age, the empirical analysis carried out in the thesis;

a. Makes a comparison (comparative case-study) between countries with contrasting financial architectures (specifically England *versus* Italy),
b. Focuses on eco-innovative companies from different industries (i.e. from all manufacturing sectors at regime level and from the hydrogen and fuel cell niche and the anaerobic digestion and biogas niche at niche level), and
c. Controls, in the questionnaires, for both size and age of eco-innovative companies investigated.

The choice to limit the comparative analysis to England and Italy, arose from two main reasons. The first, important motivation was that the above countries represent two interesting cases given the opposing configuration of their FS in terms of patterns of industrial finance, corporate governance system, financial sector, predominant system of business coordination and organisation, and legal framework (Coates, 2014; Mason and Harrison, 2013; Franks, 2009; Gola and Roselli, 2009; Hall and Gingerich, 2009; Szego et al., 2008; Barucci and Falini, 2005; Hall and Soskice, 2001). The second motivation is more practical and originates from the familiarity that the author has with both countries. This allowed minimising the time and financial efforts to collect data (e.g. in terms of costs for translating and administrating questionnaires as well as for analysing the answers collected).

The decision to focus on manufacturing enterprises (at regime level) along with companies from the Hydrogen and Fuel Cell (HFC) niche and the Anaerobic Digestion and Biogas (ADB) niche (at niche level) stemmed from the fact that EIs may occur in any business sector, since they are an integral part of the innovative effort of companies across different industries (see section 2.2.1). From this point of view, the English and Italian manufacturing industries exhibit a large percentage of innovative enterprises other than a high level of environmental protection expenditure, thus making manufacturing companies a potentially significant case-study. Similarly, HFC and ADB allow simultaneously taking into account the most relevant domains that contribute to the transition towards a more sustainable regime, i.e. energy, food, and mobility (Geels, 2013). In particular, HFC play a significant role in, both, new energy and transport systems, while ADB allows producing energy starting from a number of different feedstocks, including agricultural residues and food waste and can be used as an alternative renewable fuel for transport. Moreover, the two niches are deeply interlinked with each other; hydrogen is easily produced from biomass and biogas.

Given the different role played by eco-innovative companies at regime and niche level for a sustainability transition to occur, the thesis employed two different research methods to investigate the impact of FC upon the eco-

innovative behaviour of enterprises. More specifically, data collected at regime level were analysed econometrically by means of a probit model, which allowed estimating the probability of financially constrained companies to eco-innovate. Data gathered from the niche-level companies were analysed by means of the social network analysis, which allowed investigating the effect of FC upon the three key niche mechanisms, which define the development of a technological niche, i.e. expectations, learning process, and network formation. Given the two different research methods used, companies at regime level and niche level were surveyed by means of two different questionnaires, which have in both cases employed behavioural and attitudinal measures to investigate the extent to which FC affect the eco-innovative decisions of enterprises.

In light of the above discussion, the present methodological chapter is composed of two main parts. The first (section 5.2) deals with the regime-level analysis carried out in the thesis by discussing the context of analysis, the econometric model adopted to empirically test the impact of FC upon the eco-innovative decisions of regime-level companies, the reason for using the questionnaire for collecting data, the technique adopted for the sample selection and the questionnaire administration, and the questionnaire design. The second part (section 5.3) concentrates upon the niche-level investigation, by presenting the characteristics of the niches selected, the research method (i.e. the social network analysis) employed to analyse data, the technique adopted for the questionnaire administration, and the questionnaire design.

5.2 The regime-level investigation

This section deals with the part of the survey addressed to investigate the FC of eco-innovative companies at regime level. The section starts with a short description of the context of analysis by exploring the main characteristics of the FS (section 5.2.1) and the manufacturing industry (section 5.2.2) in the two countries. Then, it presents the econometric model employed to empirically test the extent to which FC affect the eco-innovative decisions of companies (section 5.2.3), the strategy employed to recognise eco-innovative enterprises within the manufacturing industry (section 5.2.4), and the techniques adopted for the sample selection and for the questionnaire administration (section 5.2.5). Finally, it concludes by discussing the design of the regime-level questionnaire (section 5.2.6).

5.2.1 The context of analysis (1): UK *versus* Italian financial architecture

As argued in the previous chapters, the type of financial architecture in a country can affect the extent to which eco-companies at the regime and niche levels are financially constrained. For this reason, the empirical investigation study carried out in this thesis controls for different configurations of financial architectures by implementing a comparative analysis between English and Italian eco-innovating enterprises. Indeed, in the framework of the evolutionary model presented in section 3.4.1, England and Italy exhibit very different financial architectures in regards to all five components that compose a FS (i.e. patterns of industrial finance, corporate governance system, financial sector, predominant system of business coordination and organisation, and legal framework) (Table 10).

Table 10. Main characteristics of the UK and Italian financial architectures: a comparison

	UK	ITALY
PATTERNS OF INDUSTRIAL FINANCE	▪ Market oriented	▪ Bank-centred
CORPORATE GOVERNANCE SYSTEM	▪ Outsider dominated. ▪ Very reduced presence of family companies.	▪ Insider dominated ▪ Diffused presence of family companies
FINANCIAL SECTOR	▪ Ancient and large stock exchange (LSE). ▪ Large private equity sector. ▪ Well-developed pension funds and insurance industry. ▪ Internationally opened and highly developed banking system. ▪ Corporate bond market smaller than other developed countries.	▪ Small but quite developed stock exchange (Borsa Italiana) ▪ Private equity less developed than in other European countries ▪ Small pension funds and insignificant role of insurance companies. ▪ Many national and local commercial banks but limited number of investment banks.
PREDOMINANT SYSTEM OF BUSINESS COORDINATION AND ORGANISATION	▪ Typical LME ▪ Significant distance between government and business ▪ Generally poorly organised labour ▪ Liberal-oriented organisation of economy that supports the right of managers to manage and of capital to freely move	▪ No prevailing coordination mechanism across the economy ▪ Lack of institutions strongly supporting non-market forms of strategic coordination although provided with tight labour regulations as well as a coordinating role by the State in credit provision.
LEGAL FRAMEWORK	▪ Regulated in the framework of the common law tradition. ▪ Tripartite structure (Financial Services Authority, Bank of England, and Treasury).	▪ Regulated in the framework of a long civil law tradition. ▪ Founded on some recent regulatory laws as well as on CONSOB, which is entrusted with surveillance power.

(**Source**: own elaboration based on the prevalent literature)

Patterns of industrial finance

As discussed in Chapter 3 and in section 5.1, the UK's FS may be characterised as a market-oriented system. Recently, such market-based nature has further increased because of the growing propensity of companies to be financed by capital markets. This does not imply that banks exert a marginal role in the FS, but only that their business has changed with an increase in lending to households, a reduction in the share of corporate loans and more foreign-oriented strategies. In contrast, the Italian FS is neither bank oriented nor market oriented, although it is bank centred. The rapid growth of market-based activities and the corresponding decline in the relative importance of traditional bank instruments in the 1990s did not coincide with a reduction in the role of banks, which still remains dominant.

Corporate governance system

The UK's corporate governance system is characterised by the limited extent of concentrated ownership, pyramid structures, and family ownership. The non-discriminatory treatment of shareholders in takeovers helps to explain the absence of pyramids: target enterprises are most often absorbed into the acquiring company and thus disappear as independent entities (Franks et al., 2005). However, family companies in Italy still represent almost 70.0% of the total, despite a general reduction in the presence of family blocks through pyramidal groups and/or coalition cross holdings in recent years (Franks, 2009). Dispersed ownership is still not common, thus making the market for corporate control less active than in outsider countries like the UK (Szego et al., 2008).

Financial sector

In the UK's financial sector, companies raise capital mainly in issuance of shares and in private equity, which is among the largest market in Europe in terms of number of transactions and equity invested (TheCityUK, 2014; HMRC, 2014; Mason and Harrison, 2013). In particular, 7.0% of all BA and VC investments are estimated to be made in environment/recycling/cleantech related sectors (EIM and Oxford Research, 2011). Moreover, pension funds are very well developed because of the limited role of public pensions, while the insurance industry represents the third largest in the world, after the US and

Japan (IMF, 2011). At the same time, the banking system is large, internationally open, highly developed and exhibits two distinct market configurations. On the one side, there is the retail market, which addresses domestic activity (credit to households and to SMEs), on the other, there is the wholesale market, which is characterised by the complexity of products offered, the existence of international customers, and strong competition among intermediaries. However, the UK corporate bond market is smaller compared to some other developed countries mainly because of the historic tendency of UK companies to raise debt finance through the banking system rather than through bond markets (Gola and Roselli, 2009).

Finally, it is worth mentioning that the UK is acknowledged as a global leader in Social Responsible Investments (SRIs) and the proportion of UK asset managers engaging with responsible investment strategies is constantly extending well beyond the early adopters (Eurosif, 2012). However, raising capital from markets to address the Italian FS is still quite limited because, despite the Italian stock exchange (Borsa Italiana) merging in 2007 with the LSE, it still remains quite small. Private equity is less developed than in other European countries, mainly because of the traditional importance of personal and family control of companies. However, around 8.0% of BA investments are currently estimated to be in Cleantech, with energy being the dominant sub sector (EIM and Oxford Research, 2011). Insurance companies are mainly restricted to real estate investments and government bonds and their role as financial intermediaries is not significant. Since pension benefits are provided by the Italian public pension system, pension funds represent only small institutional investors. Italian banks however control a substantial portion of, both, the insurance sector and the asset management industry. They are generally small and operate mainly in the domestic markets, where a large number of co-operative banks specialised in local financing is also active (OECD, 2009c). Finally, unlike the UK, the Italian SRI still remains a niche investment area within the asset management industry (Eurosif, 2012).

Predominant system of business coordination and organisation

The UK represents a typical example of LME, characterised by a significant distance between government and business, generally weak organised labour when compared to more coordinated market economies, and by a liberal-oriented economy organisation that supports the right of managers to manage and of capital to freely move (Coates, 2014; Hall and Soskice, 2001). In contrast, the Italian model of capitalism can be considered neither liberal-market nor coordinated-market oriented, since no specific coordination mechanism prevails across the economy and the institutional sphere. Italy is not endowed with institutions that can suitably support non-market forms of strategic coordination, although it is provided with tight labour regulations as well as a state-coordinating role in the credit provision (Hall and Gingerich, 2009). More specifically, along with indicators of CME (e.g. ownership of non-financial companies allowed to bank, increased level of wage coordination), Italy also exhibits indicators of LME, such as the wholesale privatisation of banking assets, the increased power of minority shareholders, and the decreased degree of employment protection and job tenure legislations (Hall and Gingerich, 2009).

Legal framework

The UK financial architecture is regulated in the frame of a typical common law tradition and its legal system relies on a tripartite structure composed of the *Financial Services Authority* (which is responsible for financial and banking regulation), the *Bank of England* (which contributes to the stability of the system through monetary policy), and the *Treasury* (which is responsible for the overall architecture of the system). By contrast, the Italian financial architecture is regulated in the framework of a long civil law tradition and relies mainly upon the *CONSOB* (*Commissione Nazionale per le Società Quotate e la Borsa*), which is entrusted with surveillance power, as well as upon some recent regulatory laws[16] (Barucci and Falini, 2005).

[16] In particular: the *Consolidated Law on Banking* (which has allowed commercial banks to retain stakes in non-financial companies), the *privatisation law* (which has introduced some limits to shareholding), the *Consolidated Law on Finance* (which has established a new

5.2.2 The context of analysis (2): the English and Italian manufacturing industry

The referential population for the empirical investigation at the regime level was represented by English and Italian manufacturing companies. While technological EIs developed in *specialised sectors at niche level* provide the seeds for a systemic change, incremental technological EIs and organisational EIs from *all business sectors at regime level* contribute to creating adjustments for sustainability transitions to take place. As argued in section 2.2.1, EIs, being an integral part of the innovative effort of companies across different industries, may occur in any business sector. In this framework, the English and the Italian manufacturing industries represent a particularly interesting case of study, both in terms of environmental protection expenditures (EPE) (i.e. the effort being made to prevent, reduce and eliminate pollution resulting from the production of goods and services) and innovativeness.[17] In fact, in both countries, manufacturing industries exhibit the highest level of EPE and the highest shares of innovative companies (Table 11), therefore they provide a relevant case to analyse at regime level.

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regulation on takeovers), and the *'Preda' code,* which represents an example of self-organisation for listed companies to maximise shareholders' value.

[17] More specifically, EPE represents the sum of investment expenditure (i.e. end-of-pipe pollution treatment investments and investments in integrated technologies) and total current expenditure for environmental protection (i.e. internal current expenditure related to operating environmental protection equipment and fees/purchases of environmental protection services, both from public and private producers).

Table 11 Environmental protection expenditure (EPE) and percentage of innovative companies

Sections/Divisions/Groups		Average EPE 2008-2012*	% of innovative companies 2012
B (Mining and quarrying)	UK	292.23	39.2
	IT	999.47	35.8
C (Manufacturing)	**UK**	**2,095.48**	**54.5**
	IT	**7,555.36**	**58.7**
D35 (Electricity, gas, steam and air conditioning supply) and E36 (Water collection, treatment and supply)	UK	1,715.56	19.1
	IT	2,710.18	63.1
All NACE activities except: E37 (Sewerage), E38.1 (Waste collection), E38.2 (Waste treatment), E39 (Remediation activities), and O (Public adm. and defence; compulsory social security)	UK	4,103.24	45.9
	IT	20,157.36	51.7

*Million euro

Source: Own elaboration on data from Eurostat (2015)

It is worth noting that, within the manufacturing industry, EPE exhibits remarkable differences across sectors (Table 12). In the UK, the highest percentage of EPE is recorded in the manufacture of food products, beverages, and tobacco products (23.1%), followed by the manufacture of chemicals and pharmaceutical products (12.1%), and by the manufacture of basic metals and fabricated metal products (12.0%). In Italy, manufacturing sectors with the highest share of EPE are the manufacture of coke and refined petroleum products (30.3%), the manufacture of chemicals and pharmaceutical products (17.3%), and the manufacture of food, beverages, and tobacco (10.8%).

Table 12 EPE of UK and Italian companies by manufacturing sector (year 2010) - % values

NACE rev.2	Manufacturing Sector	UK	ITALY
10-12	Food products, beverages & tobacco products	23.1	10.8
13	Textiles	0.8	0.0
14	Wearing apparel	0.2	0.3
15	Leather and related products	0.9	0.0
16	Wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.9	0.4
17	Paper and paper products	2.6	3.2
18	Printing and reproduction of recorded media	2.4	0.0
19	Coke and refined petroleum products	7.5	30.3
20-21	Chemicals and chemical products & basic pharmaceutical products and pharmaceutical preparations	12.1	17.3
22	Rubber and plastic products	5.4	6.4
23	Other non-metallic mineral products	5.8	8.8
24-25	Basic metals & fabricated metal products, except machinery and equipment	12.0	10.5
26	Computer, electronic and optical products	1.4	0.1
27	Electrical equipment	2.4	4.1
28	Machinery and equipment n.e.c.	10.8	1.2
29	Motor vehicles, trailers and semi-trailers	2.6	4.8
30	Other transport equipment	3.4	1.5
31	Furniture	2.3	0.1
32	Other manufacturing	1.0	0.2
33	Repair and installation of machinery and equipment	2.3	0.0
	TOT	**100.0**	**100.0**

EPE exhibits significant sectoral differences also in terms of environmental domains, reflecting the different type of pollution generated by companies in relation to the specific characteristics of manufacturing sectors (Table 13 and Table 14). In the UK, textiles, wearing apparel, and leather are the leading spending sectors for water protection (52.92%), chemicals and pharmaceutical products for air protection (21.09%), wood and products of wood and cork for solid waste (71.98%), coke and refined petroleum products for soil/ground water protection (24.77%) as well as for 'other' EPE (40.29%), other non-metallic mineral products for noise protection (25.75%), and food products, beverages, and tobacco for general nature protection (11.80%). By contrast, in Italy, wood and products of wood and cork is the leading spending sector for air protection (93.20%), food products, beverages, and tobacco for wastewater management (35.95%), chemicals and pharmaceutical products for waste management (28.25%), and coke and refined petroleum products for 'other' EPE (42.70%).

Table 13 EPE of the UK manufacturing companies by environmental domains (2010) - % values

NACE rev.2	Manufacturing Sectors	Water	Air	Solid waste	Soil/ Ground water	Noise	Nature protection	Other	Tot
10-12	Food products, beverages & tobacco	50.10	8.28	22.36	2.07	1.45	11.80	3.93	100.00
13-15	Textiles & wearing apparel & leather	52.92	5.57	36.21	1.39	1.39	0.00	2.51	100.00
16	Wood and products of wood and cork	12.85	4.11	71.98	0.51	1.03	0.77	8.74	100.00
17	Paper and paper products	31.72	13.99	43.28	0.19	1.49	1.68	7.65	100.00
18	Printing and reproduction of recorded media	20.33	10.47	55.44	1.64	1.85	1.64	8.62	100.00
19	Coke and refined petroleum products	8.54	11.93	14.34	24.77	0.07	0.07	40.29	100.00
20-21	Chemicals & pharmaceutical products	31.03	21.09	29.59	4.56	0.99	0.49	12.25	100.00
22	Rubber and plastic products	10.15	7.38	48.89	0.65	0.74	0.83	31.37	100.00
23	Other non-metallic mineral products	15.54	17.76	30.20	0.89	25.75	0.09	9.77	100.00
24-25	Basic metals & fabricated metal products	17.18	11.37	52.33	4.08	3.58	2.80	8.65	100.00
26 & 32	Computer, electronic, optical & other manufacturing	27.37	8.42	44.21	2.11	1.68	1.68	14.53	100.00
27-28	Electrical & machinery equipment	31.81	15.52	31.65	0.78	11.40	0.70	8.15	100.00
29-30	Motor vehicles & other transport equipment	17.65	8.40	62.18	2.52	1.68	0.84	6.72	100.00
31	Furniture	8.66	9.09	61.69	1.30	1.95	1.08	16.23	100.00
33	Repair and installation of machinery and equipment	39.34	13.87	22.77	2.48	1.86	1.45	18.22	100.00

(**Source**: own elaboration based upon data from DEFRA, 2012)

Table 14 EPE of the Italian manufacturing companies by environmental domains (2010) - % values

NACE rev.2	Manufacturing Sectors	Air	Wastewater	Waste	Other	Tot
10-12	Food products, beverages & tobacco	20.65	35.95	7.40	36.00	100.00
13-15	Textiles & wearing apparel & leather	58.67	29.6	8.40	3.33	100.00
16	Wood and products of wood and cork	93.20	0.80	3.00	3.00	100.00
17	Paper and paper products	61.90	6.70	10.30	21.10	100.00
18	Printing and reproduction of recorded media	92.60	0.00	7.40	0.00	100.00
19	Coke and refined petroleum products	16.60	17.90	22.80	42.70	100.00
20-21	Chemicals & pharmaceutical products	35.8	14.25	28.25	21.70	100.00
22	Rubber and plastic products	59.80	4.50	9.50	26.20	100.00
23	Other non-metallic mineral products	41.60	11.00	17.90	29.50	100.00
24-25	Basic metals & fabricated metal products	43.35	22.2	6.80	27.65	100.00
26 & 32	Computer, electronic, optical & other manufacturing	44.8	26.9	14.95	13.35	100.00
27-28	Electrical & machinery equipment	38.3	22.75	8.30	30.65	100.00
29-30	Motor vehicles & other transport equipment	30.15	25.1	9.05	35.70	100.00
31	Furniture	87.20	0.30	8.80	3.70	100.00
33	Repair and installation of machinery and equipment	80.20	7.80	7.80	4.20	100.00

(**Source**: own elaboration based upon data from ISTAT, 2013)

Finally, looking at the innovativeness of UK and Italian manufacturing companies (Table 15), findings from the 2011 UK innovation survey (which covers the three-year period from 2008 to 2010) shows that the highest share of innovative enterprises within the UK manufacturing industry are the electrical and optical equipments (72.0%), followed by the transport equipments (55.1%) and the fuels, chemicals, plastic metals & minerals (54.6%). By contrast, the 2011 Italian innovation survey suggests that the manufacturing sectors with the highest percentage of innovative enterprises are the transport equipments (63.8%), followed by electrical & machinery equipment, furniture, and repair and installation of machinery and equipment (52.5%), and, finally, the electrical & optical equipments (51.3%).

Table 15 UK and Italian innovative companies by manufacturing sector (2008-10) - % values

NACE rev.2	Manufacturing sectors	% of innovative companies	
		UK	Italy
10-18	Food, clothing, wood, paper, publish & print	47.9	39.7
19-25	Fuels, chemicals, plastic metals & minerals	54.6	45.9
26	Electrical & optical equipment	72.0	51.3
29-30	Transport equipment	55.1	63.8
27-28 & 31-33	Not elsewhere classified	47.7	52.5

Source: Own elaboration on data from UK and Italian innovation surveys 2011

5.2.3 The econometric model

In order to empirically test the impact of FC upon the eco-innovative decisions of English and Italian manufacturing companies, the thesis exploits an econometric model already used in literature to investigate the relationship between FC and the innovative activity of enterprises. In particular, following Mancusi and Vezzulli (2014) and Savignac (2008), the following univariate probit model was estimated:

$$y_{1i}^{*} = \alpha_1 x_{1i} + \alpha_2 y_{2i} + \varepsilon_i \qquad [5.1]$$

where:

- The latent variable y_{1i}^{*} reflects the expected return of an eco-innovative project for the regime-level company *i*. More specifically, y_{1i} is a binary

variable that reflects the decision of the company *i* to start an eco-innovative project ('propensity to eco-innovate').

- x_{1i} is a vector of independent variables representing the drivers of EIs based on the literature review discussed in Chapter 3 and then formalised in the theoretical model presented in Chapter 4 (such as company size, cost-saving needs, environmental regulation, etc.).
- y_{2i} is a regressor accounting for the existence of FC.

As argued by Hajivassiliou and Savignac (2008), the 'FC' variable (y_{2i}) could be affected by endogeneity, which may lead to bias in the estimated coefficients. The endogeneity of FC stems from two main reasons. Firstly, heterogeneous factors could affect both the eco-innovative decisions of companies as well as the probability for them to be financially constrained. For instance, the uncertainty associated with eco-innovative projects represents an unobservable company-specific risk factor that may affect the extent to which the company is financially constrained. Secondly, a potential simultaneity can happen in the company decision to eco-innovate and in the way it finances the EI (see section 3.3). To deal with the endogeneity problem when both dependent variables are binary, literature has proposed the 'Full Information Maximum Likelihood' approach (FILM) by estimating a recursive bivariate probit model (see Maddala, 1983). Following this approach, the decision to eco-innovate and the probability of becoming financially constrained were considered as simultaneous questions. In other words, the existence of FC was considered as likely affecting (reducing) the probability of eco-innovative projects, while the eco-innovative behaviour was considered as likely inducing FC in the company:

$$\begin{cases} y_{1i}^{*} = \beta_1 x_{1i} + \lambda_1 y_{2i} + u_{1i} \\ y_{2i}^{*} = \beta_2 x_{2i} + \lambda_2 y_{1i} + u_{2i} \end{cases} \quad [5.2]$$

where:

- y_{1i}^{*} is the expected return of an eco-innovative project for the regime-level company *i*.

- y_{2i} * represents the severity of FC for the regime-level company *i*.
- x_{1i} is a vector of variables representing the drivers of EIs.
- x_{2i} is a vector of variables affecting FC, based on the literature review discussed in Chapter 3 and then formalised in Chapter 4 (such as company's age, size, FS, etc.).

In this framework, the following conditions allow defining whether the regime-level company *i* was eco-innovative or not and financially constrained or not:

$$\begin{cases} y_{1i} = 1 \;\; if \;\; y_{1i}^* \geq 0 \\ y_{1i} = 0 \;\; if \;\; y_{1i}^* < 0 \end{cases} \text{ and } \begin{cases} y_{2i} = 1 \;\; if \;\; y_{2i}^* \geq 0 \\ y_{2i} = 0 \;\; if \;\; y_{2i}^* < 0 \end{cases} \qquad [5.3]$$

However, model [5.2] is logically consistent only if some restrictions are applied to coefficients. More specifically it is consistent when λ_1 or λ_2 are set equal to 0 (see Savignac, 2008, for details). In particular, by setting $\lambda_2 = 0$, the recursive bivariate probit model [5.2] becomes the following partial-recursive bivariate probit model:

$$\begin{cases} y_{1i}^* = \beta_1 x_{1i} + \lambda_1 y_{2i} + u_{1i} \\ y_{2i}^* = \beta_2 x_{2i} + u_{2i} \end{cases} \qquad [5.4]$$

In model [4] the error term u_{1i} and u_{2i} are assumed to be normally distributed according to the following bivariate normal density:

$$\begin{pmatrix} u_{1i} \\ u_{2i} \end{pmatrix} \sim \Phi\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \sigma_{1,2} \\ \sigma_{1,2} & 1 \end{bmatrix} \right) \qquad [5.5]$$

where $\sigma_{1,2} = Cov(u_{1,i}, u_{2i})$ represents the correlation between the unobservable terms that simultaneously affect the decision to eco-innovate and the likelihood of companies becoming financially constrained. It is worth noting that when $\sigma_{1,2} = 0$ then y_{2i} is not correlated with the error term u_{1i} and the two equations can be estimated separately as they would be univariate probit equations. In

contrast, when $\sigma_{1,2} \neq 0$ the two equations should be estimated simultaneously in order to achieve a consistent estimation. Moreover, despite y_{2i} being an endogenous variable, its presence in the first equation of model [5.3] does not change the likelihood of the standard bivariate probit. Therefore, the likelihood function contributions of each possible observed outcome is given by the value of the bivariate normal cumulative distribution function, as for the standard bivariate probit model without endogeneity:

$$\begin{aligned} P(y_{1i}=1, y_{2i}=1) &= \Phi(\beta_1 x_{1i} + \lambda_1, \beta_2 x_{2i}, \sigma_{1,2}) \\ P(y_{1i}=1, y_{2i}=0) &= \Phi(\beta_1 x_{1i}, -(\beta_2 x_{2i}), -\sigma_{1,2}) \\ P(y_{1i}=0, y_{2i}=1) &= \Phi(-(\beta_1 x_{1i} + \lambda_1), \beta_2 x_{2i}, -\sigma_{1,2}) \\ P(y_{1i}=0, y_{2i}=0) &= \Phi(-(\beta_1 x_{1i}), -(\beta_2 x_{2i}), \sigma_{1,2}) \end{aligned} \qquad [5.6]$$

It is worth noting that since all variables employed were dummies (0,1), the marginal effect is given by the difference between the conditional probabilities. For instance, keeping in mind conditions [5.3], the marginal effect of the existence of FC on the probability of starting an eco-innovative project was provided by:

$$P(y_1 = 1 \mid y_2 = 1, x_1, x_2) - P(y_1 = 1 \mid y_2 = 0, x_1, x_2) \qquad [5.7]$$

The description of variables used and the results achieved from the estimation of models [1] and [4] are reported in Chapter 6.

5.2.4 The identification of eco-innovative companies

The first relevant problem to estimate the econometric model described in the previous section was gathering data about eco-innovative companies mainly in terms of (i) eco-innovative decisions, (ii) drivers of EIs, and (iii) FC faced during the eco-innovative effort. In turn, this has required distinguishing between eco-innovative and non-eco-innovative enterprises within the universe of English and Italian manufacturing companies. Generally speaking, empirical literature (Cheng and Shiu, 2012; Arundel and Kemp, 2009; OECD, 2009a; European

Environment Agency, 2006) adopts different techniques in this respect, by identifying eco-innovative enterprises mainly in terms of:

- Investment expenditure for pollution control technologies. In particular, the most employed indicator is the 'Pollution Abatement Costs and Expenditures' (PACE), which measures the amount of companies' expenditure on capital equipment addressed to pollution abatement.[18] Alternatively, eco-innovative enterprises have been identified in terms of expenditure on environmental R&D or in terms of number of workers (above all scientists and engineers) employed to develop green products.
- Environmental patents granted. They refer to eco-inventions that are novel, inventive, and with a potential industrial application.
- Specific technological or organisational EIs (e.g. hybrid engines, EMAS, etc.). For instance, moving from hybrid engines, it is possible to identify companies that produce or distribute this kind of technology by means of public databases, category associations, chambers of commerce, etc. Similarly, by focusing on EMAS, it is possible to go back to EMAS verified companies by means of lists provided by EMAS national competent bodies.

It is worth noting that, in all three cases above, the identification of eco-innovative companies can be achieved by using either primary or secondary data, i.e. by developing original surveys or making use of already existing data sources. The choice depends essentially upon the aims of the research (and hence upon the research questions) as well as upon the availability of already existing databases.

However, considering the theoretical background of the present thesis and, in particular, the research hypotheses derived in Chapter 4, none of the above identification techniques seem to fit the needs of the present thesis.

The investment expenditure for pollution control technologies exhibits at least three main shortcomings. The first is that it is biased towards technological EIs. PACE, environmental R&D, and the number of 'green' workers assists identifying mainly enterprises with formal R&D, typically with formal R&D

[18] PACE are collected on an annual basis in the US, France and Germany and on an irregular basis in the Netherlands, UK, and Canada. They differ from EPE since the latter focuses both upon *investment* and *total current* expenditure for environmental protection.

laboratories, ignoring companies that have adopted organisational EIs. However, on the basis of the model developed in Chapter 4, both technological and non-technological EIs at regime level play a significant role towards sustainability transitions. Secondly, it focuses on the intention of companies to eco-innovate rather than on the results of their eco-innovative efforts. However, as discussed in section 2.2.1, EIs can be the result of the unintentional behaviour of companies. At the same time, intentional EIs can produce negative environmental effects, such as in the case of crops for biogas that can lead to the destruction of forestland. Thirdly and not less important, data about the investment expenditure for pollution control technologies carried out by companies can be unreliable, since quantifying the percentages of R&D expenditures addressed to find green solutions may be tricky for enterprises.

Similar problems occur when eco-innovative companies are identified by means of environmental patents, which generally tend to underestimate the number of eco-innovative companies. This occurs for a number of reasons. Firstly, patents are generally biased towards technological EIs. Secondly, companies do not patent all their EIs. Thirdly, patents are granted for inventions that are not necessarily already commercialised. Fourthly, they allow identifying mainly developers of EIs rather than their adopters. Finally, while some patent classes involve clearly identifiable EIs, in other cases inventions with non-intentional environmental benefits are not identified in the patent analysis. To be recognised as an ‘environmental patent’, the environmental gain must be described or, alternatively, there must be pre-existing data on the environmental benefits of a patent class.

Finally, the backward technique of identification of eco-innovative enterprises (i.e. starting from a specific EI in order to determine its developers and adopters) presents different but equally significant *caveats*. Firstly, it allows recognising only a limited number of eco-innovative enterprises, i.e. those that have developed or adopted a specific EI. Secondly, it is more valuable in cases of radical technological EIs or formalised organisational EIs (e.g. EMAS, ISO 14000 series, etc.) than in incremental technological EIs or not-formalised organisational EIs. In the latter cases, dating back to developers and adopters

becomes an impractical task. Finally, the preliminary recognition of EIs constitutes a platform that will assist the identification of eco-innovative enterprises. The question is: how to identify EIs? As discussed in section 2.2, the literature lacks a concise and universally recognised definition. Therefore the risk is that, moving from different definitions of EIs, different eco-innovative companies will be identified.

In order to overcome many of the above problems, the present thesis develops and employs a novel approach for recognising the eco-innovative enterprises at regime level. Starting from a sample of English and Italian manufacturing companies drawn from an already existent databases, this approach uses a survey strategy based upon an *ad hoc* designed questionnaire to collect information on the 'who' and 'how' of EIs. In other words, the questionnaire seeks to identify which enterprises from the sample eco-innovated ('who') and what they did to make an EI ('how') before proceeding with some more specific questions about companies' eco-innovative profiles. More specifically, the 'who' component allows identifying the eco-innovative companies while the 'how' component measures the quality or intensity of their eco-innovative effort (Arundel et al., 1998).

The distinctive characteristic of this approach is that companies surveyed are not pre-supplied with a definition of EI, but instead are asked to offer their own definition of what an EI is. Allowing respondents to provide their own opinion on what EIs are helps to understand their viewpoint on 'who' eco-innovates and avoids forcing them to adopt a definition which they may not understand or agree with, creating thus a sense of coercion that might alienate them. Furthermore, the questionnaire asks companies to list the most significant EIs that they have introduced, thus collecting the 'how' companies eco-innovated information. This approach allows identifying eco-innovative companies by overcoming the lack of a universally shared definition of EIs in the literature. It also allows collecting companies' viewpoints on what EIs are, which is not

achievable by any other means.[19] Moreover, this approach can be used in all industries, thus allowing identifying eco-innovating companies within all manufacturing sectors. Above all, this approach overcomes most of the shortcomings, which characterise the methods so far employed in the literature and discussed earlier in this section, since:

- It is not biased towards technological EIs but allows identifying companies that have developed or adopted both incremental technological EIs and organisational EIs,
- It concentrates on inventions already commercialised,
- It does not focus on the intention of eco-innovating but on the environmental results of companies' innovative efforts,
- It allows identifying a potentially large number of companies and is not limited to a group of enterprises that have implemented a specific EI, and
- It does not ask the companies their percentage committed to environmental R&D, which could be hard to quantify and isolate from the total amount of R&D expenditures.

Naturally, along the above pros, this strategy exhibits also some cons. In particular:

- It creates problems in analysing the answers where a further effort is necessary to compare responses across companies, and
- It exhibits all the typical shortcomings that characterise the surveys, in terms of low response rate, difficulties in generalising the results obtained, problems of reliability, etc. (see Yin, 2003).

However, the number of advantages relative to shortcomings seems to support the use of this method.

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[19] To the best of the author's knowledge, a similar approach was employed only in another circumstance, i.e. in the study of Cheng and Shiu (2012) who investigates EIs from an implementation perspective by asking companies' managers what EIs mean to them.

5.2.5 Sample selection and questionnaire administration

The lists of English and Italian manufacturing companies were obtained from the FAME (Financial Analysis Made Easy) and AIDA (Analisi Informatizzata Delle Aziende) databases, respectively, both provided by the Bureau Van Dijk. Both databases contain comprehensive information about companies (e.g. identification numbers, addresses, telephone numbers, trade descriptions, number of employees, detailed accounts, company financials, etc.) and are highly representative of the entire universe of corporate companies in the two countries studied. In particular, FAME covers approximately 113,000 English manufacturing companies (out of 2.8 million enterprises covered throughout the UK and Ireland). AIDA covers approximately 71,600 Italian manufacturing companies (out of 254,000 enterprises covered throughout Italy). From such a population or 'universe' of companies, a sample of enterprises was selected using a stratified random sampling strategy to avoid bias due to some companies from the population being less likely to be included in the sample than others. In order to take into account the possibility that FC are affected by type of industry and company size, the population was stratified by:

- Industry, considering all manufacturing sectors (section C – divisions from 10 to 33 according to the NACE rev.2 classification), and
- Company size, taking into account SMEs *versus* large companies according to the European Commission Recommendation 2003/361/EC, which defines SMEs as companies that employ fewer than 250 workers.[20]

In addition to the above two strata, the population of companies was also stratified by geographical area to take into account the possibility that, within the same country and, hence, within the same financial architecture, companies can be financially constrained differently across regions with different levels of

[20] Company size is particularly relevant in the Italian case where the number of large companies is quite limited. They amount to less than 3000 (8000 in Germany, 5000 in France, 6000 in the UK) and account for less than one fifth of the total employment (IPI, 2009).

GDP.[21] For this reason, England and Italy were divided into three macro-regions according to their per capita GDP. More specifically, England was divided into North-West, Southeast, and London district.[22] Italy into North, Centre, and South.[23] The sample size was calculated through the frequency estimation formula for stratified samples drawn from big populations:

$$n = \frac{z^2 Npq}{\left[e^2 (N-1) + z^2 pq\right]} \qquad [1]$$

where:

N = population size in each country

z = normal score

e = error

p = probability that the event occurs

q = $1-p$, probability that the event does not occur

By supposing z=1.96, e=0.05, and p=q=0.5, the size of a representative sample is approximately 384 companies surveyed in each country. The selection of companies from any stratum was made randomly.[24] Table 16 and Table 17 report, respectively, the percentage of targeted English and Italian companies by strata.

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[21] For instance, the Italian economy is historically characterised by a socio-economic dualism between the more advanced North and the less industrialised Centre-South of the Peninsula. The level of per capita income in the Southern regions was €17,324 in 2009, much lower than in the Centre-North (€29,399) (ISTAT, 2010). Furthermore, in 2009 about 43.0% of Italian companies were localised in the North and only 28.0% in the South (ISTAT, 2010)

[22] North-West includes the counties of Cheshire, Cleveland, County Durham, Cumbria, Herefordshire, Lancashire, Merseyside, North Humberside, North Yorkshire, Northumberland, Shropshire, South Humberside, South Yorkshire, Staffordshire, Tyne And Wear, Warwickshire, West Midlands, West Yorkshire, and Worcestershire.
South-East includes the counties of Avon, Bedfordshire, Berkshire, Buckinghamshire, Cambridgeshire, Cornwall, Derbyshire, Devon, Dorset, East Sussex, Essex, Gloucestershire, Hampshire, Hertfordshire, Isle of Wight, Kent, Leicestershire, Lincolnshire, Middlesex, Norfolk, Northamptonshire, Nottinghamshire, Oxfordshire, Somerset, Suffolk, Surrey, West Sussex, and Wiltshire.
London district includes the city of London.

[23] North includes the governmental regions of Valle d'Aosta, Piedmont, Liguria, Lombardy, Friuli Venetia Giulia, Trentino Alto Adige, Veneto, and Emilia Romagna.
Centre includes the governmental regions of Tuscany, Lazio, Umbria, Marche, and Abruzzi.
South includes the governmental regions of Campania, Molise, Apulia, Basilicata, Calabria, Sicily, and Sardinia.

[24] By means of the 'Randomize' function in the Microsoft Excel software.

Table 16 Percentage of targeted English manufacturing companies by strata

Code (NACE rev. 2)	MANUFACTURING SECTORS*	NORTH-WEST (I)		SOUTHEAST (II)		LONDON DISTRICT (III)		TOTAL (i) + (ii) + (iii)
		Large	SMEs	Large	SMEs	Large	SMEs	
10	Food products (10%)	11%	31%	11%	33%	4%	10%	100%
11	Beverages (1%)	9%	22%	19%	37%	4%	10%	100%
12	Tobacco products (1%)	1%	13%	21%	29%	14%	21%	100%
13	Textiles (2%)	8%	57%	4%	20%	3%	8%	100%
14	Wearing apparel (1%)	5%	21%	8%	31%	3%	31%	100%
15	Leather and related products (1%)	8%	19%	14%	29%	1%	30%	100%
16	Products of wood and cork (1%)	8%	42%	4%	41%	1%	4%	100%
17	Paper and paper products (2%)	5%	36%	12%	41%	1%	6%	100%
18	Printing (4%)	3%	20%	6%	53%	3%	15%	100%
19	Coke and refined petroleum products (1%)	2%	36%	14%	30%	1%	17%	100%
20	Chemical products (8%)	8%	38%	8%	33%	2%	11%	100%
21	Basic pharmaceutical products (2%)	11%	17%	25%	31%	2%	13%	100%
22	Rubber and plastic products (5%)	14%	34%	14%	33%	1%	3%	100%
23	Other non-metallic mineral products (2%)	16%	32%	12%	33%	3%	5%	100%
24	Basic metals (2%)	18%	44%	7%	19%	6%	6%	100%
25	Fabricated metal products (11%)	7%	48%	5%	35%	1%	5%	100%
26	Computer, electronic and optical products (7%)	5%	15%	9%	57%	2%	11%	100%
27	Electrical equipment (9%)	5%	25%	8%	48%	3%	11%	100%
28	Machinery and equipment (12%)	7%	35%	7%	41%	2%	7%	100%
29	Motor vehicles, trailers and semi-trailers (2%)	26%	28%	9%	28%	2%	7%	100%
30	Other transport equipment (2%)	7%	23%	14%	47%	2%	8%	100%
31	Furniture (2%)	18%	25%	7%	41%	1%	7%	100%
32	Other manufacturing (11%)	11%	31%	11%	39%	1%	8%	100%
33	Repair and installation of machinery and equipment (1%)	10%	19%	14%	44%	1%	11%	100%

*Percentage weight of sector in brackets (no. of sectoral companies divided by no. of manufacturing companies)

Table 17 Percentage of targeted Italian manufacturing companies by strata

Code (NACE rev. 2)	MANUFACTURING SECTORS*	NORTH (I)		CENTRE (II)		SOUTH (III)		TOTAL (I) + (II) + (III)
		Large	SMEs	Large	SMEs	Large	SMEs	
10	Food products (8%)	2%	57%	1%	15%	1%	24%	100%
11	Beverages (1%)	3%	58%	1%	13%	1%	24%	100%
12	Tobacco products (1%)	1%	14%	1%	55%	1%	28%	100%
13	Textiles (7%)	2%	63%	1%	29%	1%	4%	100%
14	Wearing apparel (4%)	1%	55%	1%	28%	1%	14%	100%
15	Leather and related products (4%)	1%	36%	1%	47%	1%	14%	100%
16	Products of wood and cork (2%)	1%	68%	1%	18%	1%	11%	100%
17	Paper and paper products (2%)	2%	60%	1%	26%	1%	10%	100%
18	Printing (4%)	2%	68%	1%	22%	1%	6%	100%
19	Coke and refined petroleum products (1%)	3%	38%	2%	24%	1%	32%	100%
20	Chemical products (4%)	5%	69%	1%	15%	1%	9%	100%
21	Basic pharmaceutical products (5%)	2%	73%	1%	13%	1%	10%	100%
22	Rubber and plastic products (5%)	2%	56%	1%	23%	1%	17%	100%
23	Other non-metallic mineral products (2%)	4%	74%	1%	13%	1%	7%	100%
24	Basic metals (4%)	1%	77%	1%	12%	1%	8%	100%
25	Fabricated metal products (14%)	2%	81%	1%	11%	1%	4%	100%
26	Computer, electronic and optical products (9%)	1%	65%	1%	21%	1%	11%	100%
27	Electrical equipment (5%)	2%	75%	1%	13%	1%	8%	100%
28	Machinery and equipment (6%)	4%	67%	1%	21%	1%	6%	100%
29	Motor vehicles, trailers and semi-trailers (2%)	3%	79%	1%	11%	1%	5%	100%
30	Other transport equipment (1%)	6%	69%	1%	13	1%	10%	100%
31	Furniture (1%)	3%	59%	1%	23	1%	13%	100%
32	Other manufacturing (7%)	1%	63%	1%	28	1%	6%	100%
33	Repair and installation of machinery and equipment (1%)	1%	59%	1%	21	1%	17%	100%

*Percentage weight of sector in brackets (no. of sectoral companies divided by no. of manufacturing companies)

Gathering information about companies' behaviour is generally quite a challenging task for researchers. Enterprises are often reluctant to be surveyed about information that they may consider reserved. It was no wonder, and actually not unexpected, that many enterprises explicitly refused to be surveyed or completed the questionnaire only partially. Consequently, with an expected low response rate, the number of companies that had to be contacted in order to meet the targeted number of at least 768 in total (i.e. 384 from England and 384 from Italy) was significantly high. For instance, with an expected response rate of 30% in both the English and Italian samples, the number of companies that had to be contacted in order to achieve this response rate was 2,563, which increases to 3,854 in the case of a 20% response rate and to 7,690 in the case of a 10% response rate. Such high numbers required a quick, cheap, but also reliable way to collect answers, and the best solution was represented by the administration of computer-assisted interviews. More specifically, the questionnaire was initially computerised by using the 'Obsurvey' web service (http://obsurvey.com/). Then, it was tested among colleagues and a restricted number of pilot companies in order to collect feedback and suggestions/advice to refine the questions. In particular, the pilot test addressed to companies provided very useful insights into the way enterprises interpreted the questions and thus assisted with a noticeable improvement to the final questionnaire's design. Thus, after a number of amendments, the survey was officially launched on May 2012 and concluded on February 2013 when the targeted number of companies was finally reached.

Over this 10-month period, companies selected were firstly contacted telephonically with the purpose to inform them about the research purposes of the thesis and to identify the most appropriate person in charge within the enterprise to answer the questionnaire (director, strategic planning manager, etc.). Although companies were telephonically encouraged to allocate time to complete the questionnaire, many enterprises expressly refused to be surveyed. In such cases, the sample was promptly refilled by randomly selecting another company from the same stratum as the refusing enterprise. However, when an enterprise agreed to be surveyed, the questionnaire was administered using the CAWI (Computer Assisted Web Interviewing) technique.

In other words, respondents received a web-link to the questionnaire via their inbox, allowing them to fill out the questionnaire online.[25] Silent companies automatically received two reminder emails (after 15 and then 30 days) and, in the case of no feedback, after a further 15 days (i.e. after 45 days from first contact) they were excluded from the sample and replaced with other enterprises from the same stratum.

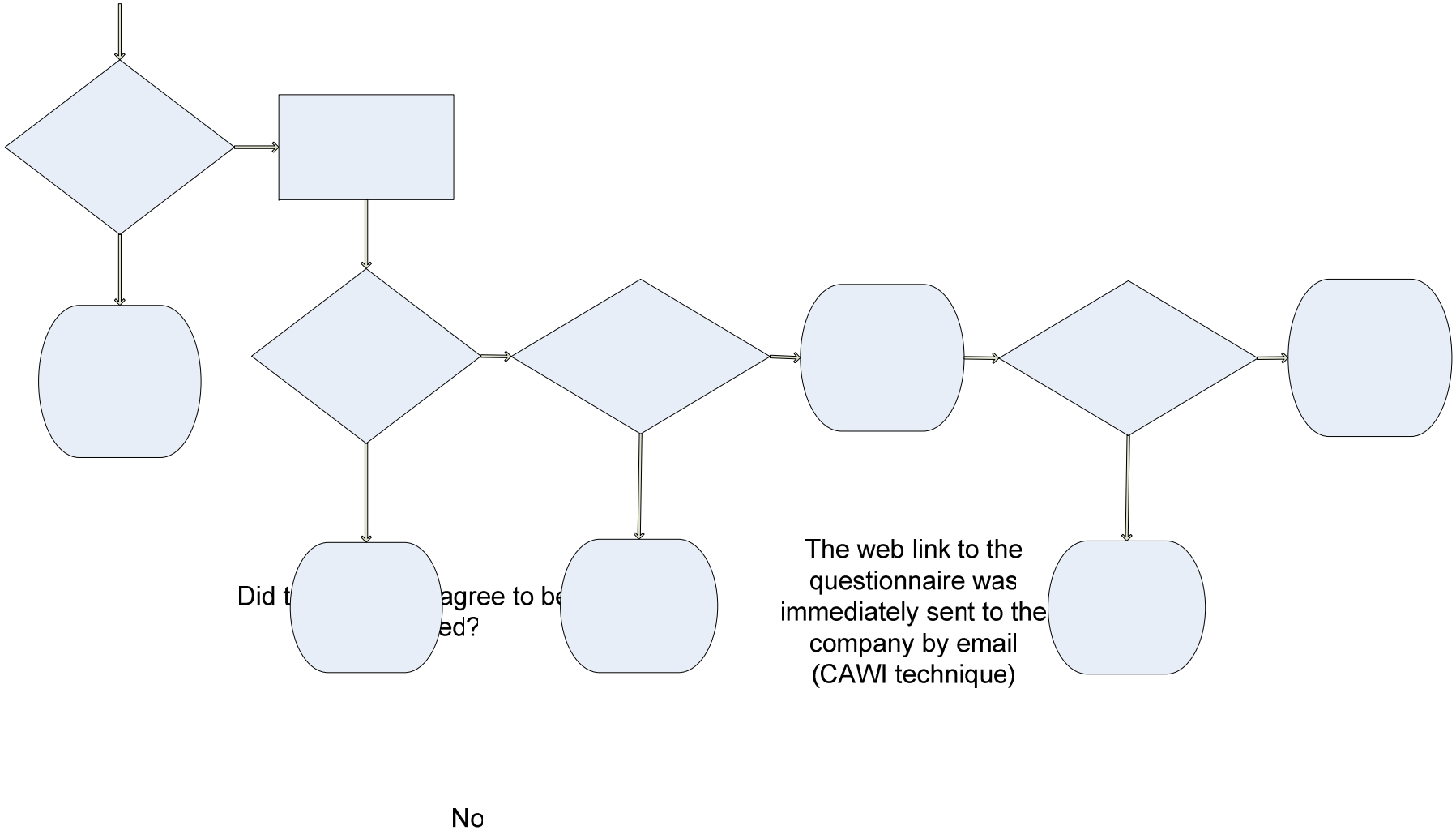
The CAWI technique has represented an effective and very affordable way of collecting companies' points of view. Answers to the questions were automatically imputed after they were filled in, allowing continual tracking of the data collected and the results achieved, as well as considerably speeding up the process of analysing the responses. Moreover, the computerised environment has enabled great logical intricacy in the surveying process, allowing for an interactive questionnaire that filters and processes logical relationships out of sight, while only the relevant questions appear on the respondent's screen.[26] Certainly, the CAWI technique lacks the possibility of explaining the questions to the respondent when these are not fully understood. For this reason, questions were formulated in the simplest and shortest possible way, while also providing the respondent with definitions and/or explanations where necessary. Moreover, the absence of an interviewer can reduce the number of incomplete surveys returned. Therefore, the questionnaire adopted internal requests for completion of 'compulsory fields' and 'validation checks' for the most significant questions, encouraging respondents to provide at least consistent and relevant information. This also represented the first step towards the validation process of responses, since a fully answered questionnaire or a questionnaire that answered at least all compulsory fields was considered complete and hence was assessed for validation of responses. By contrast, a questionnaire that was started but suspended was considered incomplete after 45 days from the administration date and therefore it was not assessed for validation. In such cases, the company was replaced by another enterprise

[25] Along with the web-link to the questionnaire, the respondent also received a short introduction concerning the purpose of the study and a guarantee of confidentiality.
[26] Questions were not numbered and the respondents could not know the questionnaire length since only a percentage progress bar appeared on their screen.

randomly selected from the same stratum. Validation of complete questionnaires was assessed by looking at the consistency of answers in terms of reliability, number of ‘don’t know’ answers, and role of the respondent within the enterprise. Only data from ‘valid’ questionnaires were registered and used for the empirical analysis. Companies that provided an ‘invalid’ questionnaire were deleted from the dataset and replaced. Validation assessment was therefore carried out continuously throughout the administration process in order to promptly replace companies whose questionnaires were incomplete or invalid.

Figure 15 summarises and schematises the administration process and the validation strategy adopted. A detailed description about the number of companies contacted and invited to take part in the survey, the response rate, the percentage of complete, incomplete, valid and invalid questionnaires returned will be provided in the next chapter.

Figure 15 Questionnaire administration and validation strategy



5.2.6 The regime-level questionnaire explained

This section describes the architecture of the questionnaire employed to collect data at the regime level and discusses the aim of each question. In general terms, the questionnaire tried to collect relevant information about the pressures affecting companies' eco-innovative decisions at regime level, the aims of eco-innovative efforts pursued by enterprises (e.g. green motivations, usual business goals of cost minimisation and profit maximisation, etc.), the potential financial barriers that could impede companies to eco-innovate, and the role of companies' environmental reputation to reduce possible FC. The use of the CAWI technique enabled filtering the questions according to the respondent's answers, thus creating a very interactive questionnaire that allowed maximising the information from companies surveyed, even in the case of non-innovative enterprises. In particular, two questions (no. 3 and no. 6) filtered the questionnaire in order to tailor it to three possible company profiles, i.e., eco-innovative enterprises, innovative but not eco-innovative enterprises, and non-innovative enterprises. More specifically, the questionnaire can be ideally divided into six parts. The first (introductive) and the sixth (concluding) parts were common to all companies from the sample. The second part was addressed to innovative companies in general (both non- and eco-innovative). The third was specifically addressed to companies that declared being eco-innovative. The fourth to companies that, although having declared being innovative, had not introduced any EIs. The fifth to companies that did not innovate. The total number of questions amounted to 22 although any innovative profile of companies was called to answer a different number of questions varying from 7 to 14 (Table 18).

Table 18 Number of questions addressed according to companies' innovative profile

	Companies		
	Innovative and also eco-innovative	Innovative but not eco-innovative	Non-innovative
First part (questions 1 to 3)	√	√	√
Second part (questions 4 to 6)	√	√	
Third part (questions 7 to 13)	√		
Fourth part (questions 14 to 17)		√	
Fifth part (questions 18 to 21)			√
Sixth part (question 22)	√	√	√
Total number of questions	**14**	**11**	**7**

First part (questions 1 to 3): all companies

The first part of the questionnaire was common to all types of companies (i.e. eco-innovative, innovative but not eco-innovative, and non-innovative). After a 'welcome page' that briefly informed the respondent about the aims of the questionnaire and the estimated time of completion, the questionnaire started to collect preliminary information about companies in terms of age, stage of development, and innovative profile.

- **Questions no. 1 and no. 2** asked year of establishment and stage of development of companies, respectively.[27] Such information allowed distinguishing between younger and older enterprises. This information (which was not available from the FAME and the AIDA datasets) is relevant in light of the negative correlation between companies' age and degree of FC asserted in the literature (see section 3.4). Both questions were multiple choice (single answer queries). In particular, question no. 1 offered five ranges of years (i.e. 'before 1980', '1980-1990', '1991-2000', '2001-2006', and '2007-2012') in order to avoid a too specific question that the respondent would not be able to answer. Question no. 2 offered four possible options (i.e. 'seed', 'start-up', 'expansion', and 'later stages').[28] Both questions had the option to answer 'don't know', in case the respondent was

[27] In the case of a Multinational Enterprise (MNE), both questions expressly referred to the national affiliate. This was to avoid any possible confusion since, in the case of MNEs, the respondent could interpret the question as referring to the entire MNE (including subsidiaries in other countries), or to a single plant only.

[28] Instead of including additional explanatory material, definitions of stages were provided just next each to the option, since a sizeable fraction of the respondents generally does not read the explanations. Furthermore, reading definitions is time consuming whereas turning the definitions into the response categories contributes to a more effective use of time.

not able to answer. This option was placed at the bottom of the page to encourage the respondent to first read all the categories.[29]

- **Question no. 3** dealt with the innovative profile of the company, by asking if the enterprise introduced any product, process, organisational, or marketing innovation during 2007-2012.[30] Definitions were taken from the CIS VII - 2010 survey and were provided next to the question to avoid wasting respondents' time that could negatively influence the response rate. The definition of innovation was provided since companies might believe that their inventive efforts represented innovations although not yet commercialised. The questionnaire tried to minimise such a risk (and the consequent risk of not obtaining any useful information from enterprises) by presenting the definition of innovation but leaving companies free to provide their own definition of EIs in the next answers (i.e. in questions no. 4 and no. 5). The questions were multiple choice (multiple answers) to give enterprises that introduced more than one type of innovation during the period considered the possibility to select more than one option. These questions filtered the innovative from the non-innovative enterprises. Indeed, after question no. 3, the questionnaire split: if the company was innovative (i.e. if the respondent answered at least one 'yes' to the question) the questionnaire continued to question no. 4. Otherwise the respondent was automatically re-directed to question no. 19 where, although not innovative, the company was asked its point of view about definition and drivers of EIs. In this way, the questionnaire maximised the information achievable from the companies surveyed, including the non-innovative ones.

Second part (questions 4 to 6): innovative companies

The second part of the questionnaire was tailored to innovative enterprises only (both eco-innovative and non-eco-innovative) and collected information on the definition of EIs, the environmental problems at industry level, and the EIs introduced by the company.

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[29] The 'don't know' option was employed in many questions of the questionnaire in order to identify the level of reliability of the respondent.

[30] The question did not ask who developed each innovation (if mainly the enterprise surveyed or other enterprises), since it was outside the aims of the present research. However, eco-innovative companies were asked this later in the questionnaire (question no. 8).

- **Question no. 4** introduced the term 'eco-innovation' for the first time in the questionnaire. The question asked the respondent what they thought was an EI. With this question the questionnaire reached one of its crucial points since the respondent was asked to provide his own definition of an EI in light of the definition of innovation provided earlier in the questionnaire (question no. 3).
- **Question no. 5** is the logical consequence of the previous question and asked the respondent the reasons for categorising an innovation as an 'EI'. The question was helpful to gather further insights about companies' viewpoints on the topic and, at the same time, allow the respondent to reflect on their answer to the previous question.
- Finally, **question no. 6** asked the respondent if the company introduced any EIs during 2007-2012. This was another filter question to guide the respondent along one of two routes that the questionnaire now took. The question provided only two options (i.e. 'yes' or 'no'): if the company eco-innovated (i.e. the respondent answered 'yes' to the question) the questionnaire proceeded with question no. 7. Otherwise the questionnaire moved to question no. 14 where the respondent was asked questions about the possible pressures received to eco-innovate, about the role that FC had on the company's decision to not eco-innovate, and about the environmental profile of the company. As explained earlier, this was done to maximise the information achievable from the questionnaire administration.

Third part (questions 7 to 13): eco-innovative companies

The third part represented the core of the questionnaire and was tailored to eco-innovative enterprises. It collected information on drivers of EIs, sources of finance, and accessibility and barriers to financial sources.

- **Question no. 7** asked for a description of the three most significant EIs introduced by the company in decreasing order of their importance. The respondent could indicate up to three EIs. The question was thus crucial to identify the most significant EIs introduced by the companies surveyed.
- **Question no. 8** asked who developed the EIs described in the previous answer. Basically, the question aimed to understand if the company was manly a developer or an adopter of any EI introduced. The question was a

matrix of choices (single answer query) that allowed rating multiple items (i.e. each EI introduced) although only a single option out of four could be chosen for each item (i.e. 'mainly your company', 'your company together with other companies or institutions', 'exclusively other companies or institutions', and 'don't know'). The presence of a text box provided the possibility of optionally commenting on the topic.

- **Question no. 9** dealt with the EI drivers by asking the companies how important the listed reasons were in their decision to eco-innovate. The question was a matrix of choices (single answer queries), which take into account the internal-to-company and external-to-company drivers from the literature review discussed in Chapter 3 and then reported in the theoretical model developed in Chapter 4. The multiple items were: 'comply with environmental regulations', 'customers' demands', 'pressure from environmentalists or consumer groups', 'increase your company's competitiveness', 'suppliers' demands', 'pressure from industry associations', and 'reduce production costs'.[31] A four-option Likert scale (1 = not important to 4 = very important) was employed to avoid any possible neutral answers on an odd-numbered scale. Along with the Likert scale, the 'don't know' option was also provided. As usual, a text box provided the possibility of optionally commenting on the topic. A company that rated a driver as 'not important' was considered as not having received any pressure from that driver.
- **Question no. 10** asked about the sources of finance employed to eco-innovate. The question was a matrix of choices (single answer queries). It included the following items: 'own source / equity', 'share capital', 'corporate bonds', 'bank loans', 'private equity (VC, BAs, etc.)', and 'public support'. Three options ('yes', 'no', and 'don't know') along with the usual text box for optional comments were provided.
- **Question no. 11** dealt with the FC by asking companies how significantly did they feel financial barriers constrained their eco-innovative activity. The question was a matrix of choices (single answer queries). The multiple items

[31] Information about company size achieved from the FAME and the AIDA datasets allowed to organise data collected between SMEs and large enterprises, allowing thus to assess also the impact of company size upon the eco-innovative behaviour of enterprises.

were: ‘potential financial suppliers insufficiently engaged with eco-innovative projects’, ‘financial suppliers expected returns are different from your business goals’, ‘available finance not tailored to small-scale investment needs’, ‘financial supplier requested an unacceptably high level of control of your business’, ‘lack of technical experience in your business as perceived by financial supplier’, ‘lack of business experience in your business as perceived by financial supplier’, ‘insufficient amount of collateral available’, ‘limited resources dedicated to seeking or securing finance’.[32] A four options Likert scale (1 = not significant to 4 = very significant) was used to avoid possible neutral answers on an odd-numbered scale. Along with the Likert scale, the ‘don’t know’ option and the text box for optional comments were also provided. This question allowed to define whether the eco-innovative companies surveyed were financially constrained or not. More specifically, after deriving the frequency distribution for any option provided (i.e. 1, 2, 3, and 4) companies were considered not financially constrained if their weighted average of answers (WAA) was lower than 1.75, and financially constrained otherwise.[33]

- Finally, **questions no. 12 and no. 13** asked companies whether they believed that financial barriers faced in eco-innovating were the same as for other types of innovations. In particular, question no. 12 asked the companies whether their environmental reputation somehow affected their access to funding EIs. Question no. 13 asked whether accessing finance was easier for eco-innovative investments than for other types of innovation. Both questions were multiple choice; single answer queries, where ‘yes’, ‘no’, and ‘don’t know’ were the only possible answers provided. Basically, the questionnaire for eco-innovative companies ended here. Regardless of the answer chosen to question no. 13, the respondent was automatically re-directed to question no. 24 (where he was asked identification information) and then to the final page where he could provide free comments on the questionnaire.

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[32] Questions no. 11 was adapted from ‘EIM and Oxford Research survey (2011).
[33] This threshold was obtained by dividing the range of possible answers (from 1 to 4, i.e. 3) by the number of possible options (i.e. 4).

Fourth part (questions 14 to 17): non-eco-innovative companies

The fourth part of the questionnaire was tailored to innovative companies that did not eco-innovate during 2007-2012. This part collected information on the possible pressures received from companies to eco-innovate (although such pressures failed to drive these enterprises to make eco-innovative investments). Furthermore, it investigated the role of FC in the decision of companies to not eco-innovate.

- **Question no. 14** dealt with the pressures, if any, received from the company to eco-innovate. More precisely, it aimed at investigating if the enterprise did not eco-innovate despite pressures received from 'regulatory bodies', 'customers', 'environmentalists or consumer groups', 'other companies', 'suppliers', 'labour unions or industry associations', or 'inside the company' (cost-saving needs). The question was a matrix of choices (single answer queries). The usual text box for optional comments was also provided.
- **Questions no. 15** investigated the FC of non-eco-innovative companies by asking to what extent financial barriers hindered them from eco-innovating. The question was a matrix of choices (single answer queries). The multiple items and the options provided were the same used in question no. 11. Moreover, similarly to question no. 11, this question allowed defining whether the non-eco-innovative companies surveyed were financially constrained or not. As before, a company was considered not financially constrained when the WAA was lower than 1.75, and financially constrained otherwise.
- Finally, **questions no. 16 and no. 17** asked companies if they believed that a company's environmental reputation could affect the access to funding EIs (question no. 16) and whether accessing to finance was easier for eco-innovating investments than for other kinds of innovations (question no. 17). These two questions are therefore similar to questions no. 12 and no. 13, which were targeted to eco-innovative enterprises. Both of them were multiple choice; single answer queries and the options provided were 'yes', 'no', and 'don't know'. The main questions addressed to non-eco-innovative companies ended here. Regardless of the answer provided to question no. 17, the questionnaire moved to question no. 24 and then to the final page.

Fifth part (questions 18 to 21): non-innovative companies

The fifth part of the questionnaire was tailored to non-innovative companies with the aim of maximising the quantity of information from all types of enterprises surveyed. This part collected the point of view of companies on the definition and drivers of EIs and investigated to what extent FC hampered the eco-innovating decisions of enterprises.

- **Questions no. 18 and 19** are the same as questions no. 4 and 5, but are addressed to non-innovative enterprises.
- **Question no. 20** asked about the possible pressures that the company received to eco-innovate (as for question no. 14, which was targeted to non-eco-innovative enterprises), despite the final decision of the enterprise to not innovate.
- **Question no. 21** investigated the FC of non-innovative enterprises by asking to what extent financial barriers hindered them from eco-innovating. The question was a matrix of choices (single answer queries) with the same multiple items and options provided in questions no. 11 and no. 15. The question allowed to define whether non-innovative companies surveyed were financially constrained or not. As before, a company was considered to not be financially constrained if their WAA was lower than 1.75, and financially constrained otherwise.

Sixth part (question 22 and conclusion): all companies

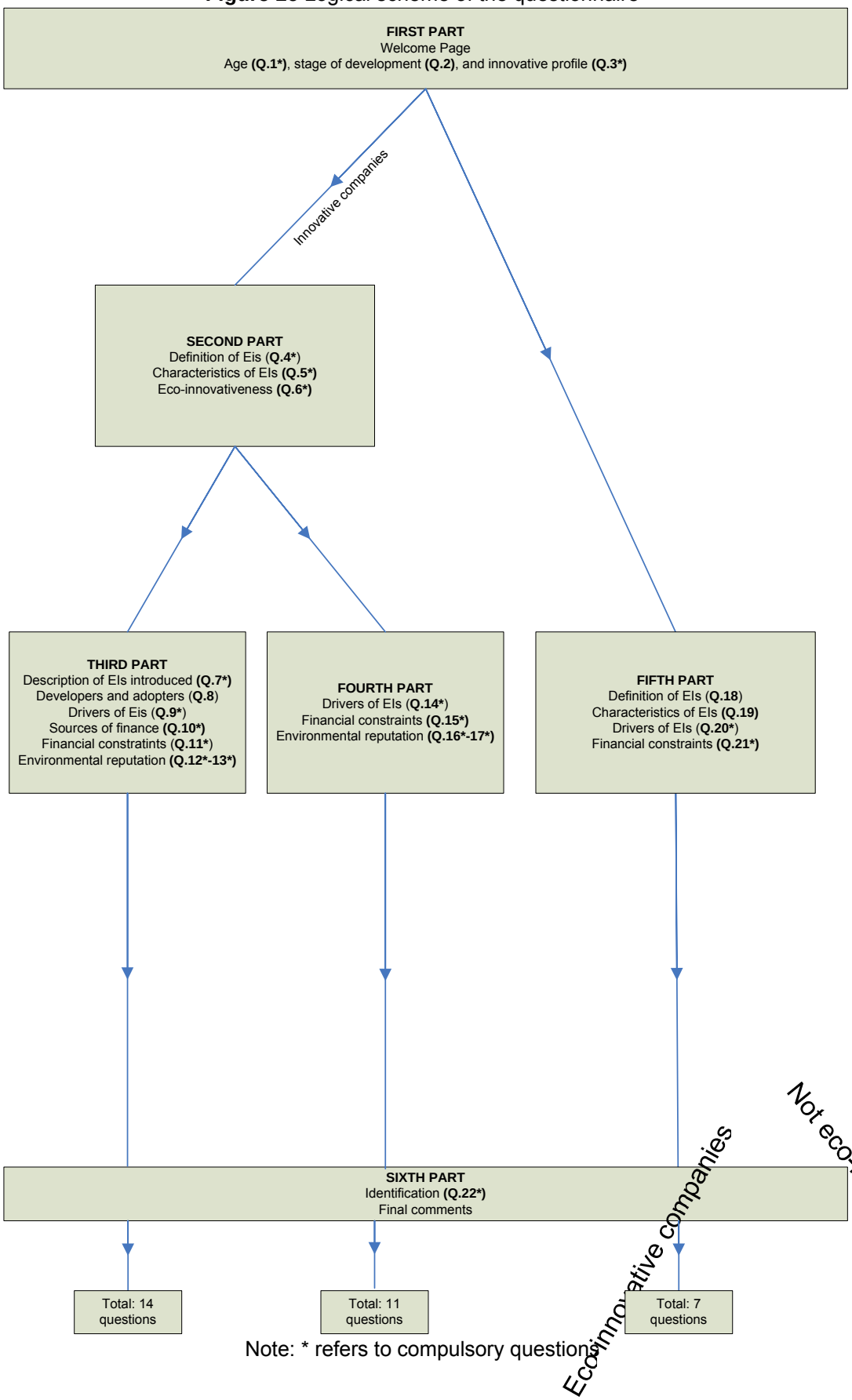
The sixth part of the questionnaire was addressed to all enterprises (i.e. eco-innovative, innovative but not eco-innovative, and completely non-innovative) and collected identification information from the respondent before proceeding towards the concluding page, which provided a text box for additional free comments on the questionnaire and thanked the respondent for collaborating. In particular, **Question no. 22** gathered information about the company's name, respondent's name, and respondent's job position within the company. The first information (company's name) was useful to identify the enterprise. The second and the third (respondent's name and job position within the company) to

assess the level of competence of the respondent for the questionnaire validation.[34] It is worth noting that, despite other innovation surveys, no additional information about the enterprises were requested (e.g. company's sector, number of employees, contact information) since they were already provided from the FAME and AIDA datasets utilised to select surveyed companies. As a result, all respondents' times were optimised to collect more targeted information about relevant variables.

Figure 16 summarises the structure of the questionnaires and reports its logical scheme. The full questionnaire (in English and Italian) is reported in the Appendix, at the end of the thesis.

[34] For instance, staff from a company's account office is less informed about the eco-innovative decisions than the entrepreneur or a company's manager.

Figure 16 Logical scheme of the questionnaire



Note: * refers to compulsory questions

5.3 The niche-level investigation

This section deals with the part of the case study investigating the FC of eco-innovative companies at the niche level in England and Italy. The section starts with a short overview of the context of analysis (section 5.3.1), by describing the two niches selected for the empirical investigation, i.e. the hydrogen and fuel cells niche (section 5.3.1.1) and the biogas and anaerobic digestion niche (section 5.3.1.2). Then it discusses the research method employed to address the research question (i.e. the social network analysis, section 5.3.2) and the technique adopted for identifying eco-innovating companies and for administrating the questionnaire (section 5.3.3). Finally, the section concludes with a design and description of the niche-level questionnaire (section 5.3.4).

5.3.1 The context of analysis

As discussed in Chapter 4, along with external conditions at the landscape level and changes in the sociotechnical regime, the ultimate success of a sustainability transition depends upon the development of niches where radical technological EIs have been previously tested and assessed. In this framework, the present thesis specifically investigates the case of the following two niches:

1. The Hydrogen and Fuel Cells (HFC) niche.
2. The Anaerobic Digestion and Biogas (ADB) niche.

The first includes actors involved in the production of energy from fuel cells, i.e. devices that combine hydrogen and oxygen to provide electricity, heat, and water. The second consists of operators involved in the anaerobic digestion process, which is the breakdown of organic material by microorganisms in the absence of oxygen. Anaerobic digestion enables the production of biogas, a methane-rich gas that can be used as a fuel, and digestate, a source of nutrients that can be used as a fertiliser.

The reason for focusing on the above two niches stems from the following two considerations. Firstly, they allow simultaneously taking into account the most relevant domains, which can actively contribute to the transition towards a more sustainable regime, i.e. energy, food, and mobility (Geels, 2013). In particular,

HFC play a significant role in, both, new energy and transport systems while ADB allows producing energy starting from a number of different feedstocks, including agricultural residues and food waste and can be used as an alternative renewable fuel for transport. Moreover, the two niches are deeply interlinked with each other; hydrogen also being easily produced from biomass and biogas. Secondly, the niches selected exhibit a remarkably different level of development, thus allowing assessment of the impact of FC on niches with a different degree of readiness. In particular, the HFC niche is actually not yet fully formed as an industry, being rather a cluster of companies with different technologies, applications, and supply chains. In contrast, the ADB niche represents a more developed and widespread sector with thousands of agricultural biogas plants and millions of small-scale anaerobic digesters, which are nowadays in operation all over the world.

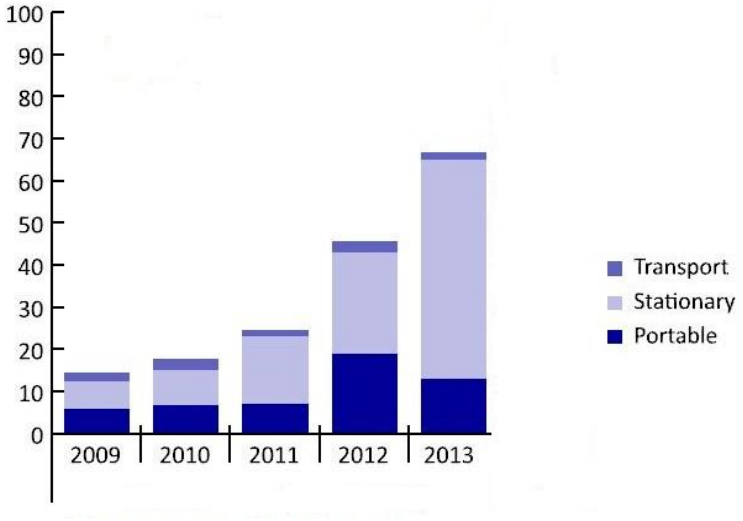
5.3.1.1 The HFC niche

At the global level, the HFC niche still represents a thin and fragile sector, although it is slowly strengthening over time. It is characterised by actors who are focused exclusively on their individual area of strength, thus lacking companies with a diversified supply of HFC solutions (Hart et al., 2014). More specifically, large companies are more oriented towards residentially combined heat and power (CHP) and automotive applications, which represent some of the hardest markets to enter due to low price points, strong incumbency, and a need for coalition approaches. SMEs are, however, more specialised at materials handling, telecommunications backup, and small-scale portable devices, which represent smaller markets that attract less interest from large actors.

Figure 17 provides a picture of the HFC global market by application, showing that the most relevant shipments have, so far, involved mainly stationery (residential CHP, large stationery systems for prime power, stationery backup power), followed by portable (fuel cells for charging consumer electronics, most notably mobile phones; auxiliary power units in leisure applications, such as

camper vans; military use for soldier power), and transport (car, buses, etc.) energy suppliers/fuel cells.

Figure 17 HFC global market: shipments by application (2009-2013) (1,000 units)



(**Source**: adapted from Hart et al., 2014)

At the regional level, the HFC market is concentrated mainly in Asia, North America, and Europe. In particular, Europe has the smallest final market of the above three regions despite a quite large HFC niche, with fuel cells for consumer electronics, backup power, and stationary as the main applications produced (Hart et al., 2014). Turning our attention specifically towards the English and Italian cases, it is worth noting that the HFC sector in the two countries looks quite dissimilar. On the one hand, the UK HFC niche actively contributes to the realisation of the country's environment and energy goal of achieving the CO_2 cuts that the country is committed to delivering and is becoming one of the crucial sectors for driving the UK's transition towards a low carbon economy. Along the full length of the commercial value chain (from R&D to systems integration, from finance to servicing), the niche involves mainly England-based international corporations, English smaller entrepreneurial companies, and other 'institutional' actors (e.g. government departments, environmental/energy associations, universities, research-related partners, etc.). On the other hand, the Italian HFC niche seems to be still in its early stage of development. It involves only four main companies (one of which is a foreign multinational corporation) together with a limited number of enterprises (mainly

SMEs) and institutional actors along the full value chain. Unfortunately, the lack of official statistics does not allow any comparison to be made regarding the amount of energy produced from HFC in the two countries.

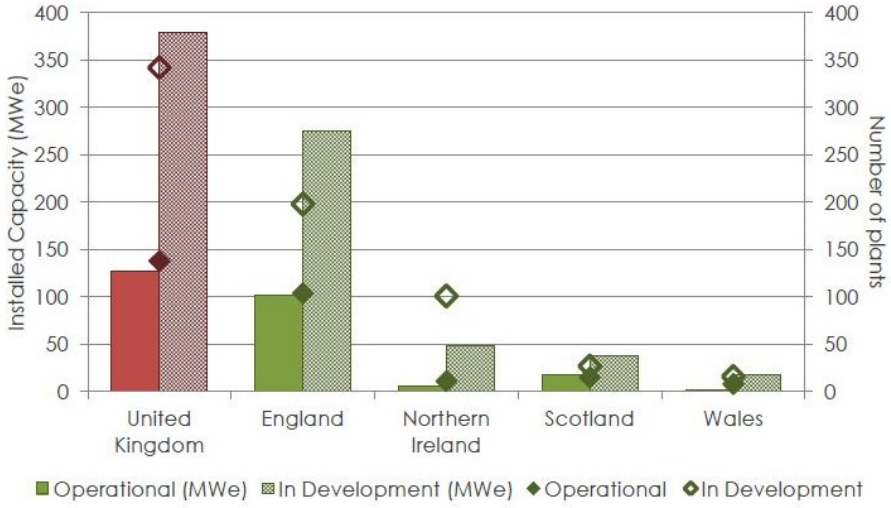
5.3.1.2 The ADB niche

Biogas represents a highly versatile source of renewable energy that enables the production of heat, steam, electricity, and vehicle fuel. It is produced during anaerobic digestion and exhibits at least three relevant characteristics. The first is that it can be produced starting from a number of different organic substrates, such as agricultural residues, energy crop (maize), manure, sewage sludge, as well as the organic fraction of household and industry waste. The second is that it can be employed either for the decentralised production of electricity and heat or for all applications designed for natural gas, since upgraded biogas can be fed into the natural gas grid. The third is that the remaining fraction after anaerobic digestion (i.e. the digestate) represents a perfect natural fertiliser that contains nearly 100% of the nutrients from the substrates (EBA, 2011).

At the European level, biogas production has constantly increased over the last decade with more than 14,560 biogas power plants operating in Europe in 2014, with a total capacity approaching 7.9 GW (Ren21, 2015). Germany is still the biggest European biogas producer followed by a number of countries including Italy, France, and the UK (EBA, 2013). In both England and Italy, the overall network of ADB actors (i.e. operators, plant suppliers, governmental institutions, universities, research centres, utilities, etc.) seems to have reached a significant level of development, particularly in comparison to the HFC sector. In particular, Italy represents the second European country in terms of number of installed anaerobic digestor plants (1,264) (EBA, 2013). The biogas production at the national level has rapidly moved from 1,336.3 GWh in 2006 to 4,619.9 GWh in 2012 (CIB, 2015). Most anaerobic digesters are located in the north of the country, although, in very recent years, many southern farms are increasingly endowed with small-scale digesters. In the UK the number of plants that are currently under development amounts to 300, while 138 are already operating, 65 of which are farm-fed (i.e. with a contribution of farm-based

feedstocks towards the total feedstock requirement greater than 50%), and 73 waste-fed (in this case more than 50% of the total feedstock requirement comes from municipal, commercial, and industrial wastes) (Goldsworthy, 2014). It is worth noting that England exhibits the strongest deployment of anaerobic digesters in the UK in terms of, both, number of plants and installed capacity (Figure 18).

Figure 18 Number and installed capacity of anaerobic digesters across UK by countries (2014)



(**Source**: Goldsworthy, 2014)

5.3.2 The Social Network Analysis

The possibility that FC prevent the development of radical technological EIs at niche level, thus hindering a sustainability transition from occurring, has been analysed within the framework of the strategic niche management perspective by looking at the architectural characteristics of the two niches selected (i.e. the HFC and ADB niches). To this end, the research method employed in this thesis was the Social Network Analysis (SNA), which has emerged as a key technique in social sciences to investigate social relationships in terms of nodes (i.e. the individual actors within the network) and ties (i.e. the relationships between actors). The emphasis lies therefore on the relationships and the ties between actors within the network, and the structure of the network, as well as the quality of the relations, are the main determinants of its usefulness to its participating individuals. The core unit of analysis is the social network defined

as '*a specific set of linkages among a defined set of persons with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behaviour of the persons involved*' (Mitchell, 1969: 2). That is, '*a social network consists of a finite set or sets of actors and the relation or relations defining them*' (Wasserman and Faust, 1994: 20). Some relevant basic concepts of network analysis that are worth mentioning are:

- Actors and their actions are viewed as interdependent rather than independent units.
- Relational ties between actors are channels for transfer or flow of resources (knowledge and expectations, in this case).
- Network models focusing on individuals view the network structural environment as a source of opportunities for, or constraints on, individual actions.
- Network models conceptualise structure as lasting patterns of relations among actors (Wasserman and Faust, 1994).

The SNA method provides an explicit formal way of measuring social structural properties (referred to actors in a given set). In other words, this tool seeks to model the relationships among a set of actors to describe the structure of the network. In this framework, the thesis assesses the effect of FC on the architectural characteristics of the HFC and ADB networks in England and Italy, by focusing upon the three key niche mechanisms that define the development of a technological niche, namely, (1) expectations, (2) learning process, and (3) network formation. As discussed in section 4.3.3, expectations are based on tangible results from experiments. They are relevant in order to attract new actors and resources, mainly when radical technological EIs are still in their early stages of development. In particular, upward convergence of expectations requires that an increasing number of actors in the network share a common positive view on the future development of the niche. The second mechanism (learning process) is widely recognised as crucial for successful innovation. It can occur both collectively (i.e. when actors involved in the technological niche share the possessed knowledge) and individually (i.e. when producers increase their knowledge simply 'by doing'). Finally, the third mechanism is the building of social networks, which is effective for niche development when the network is broad (i.e. it includes producers, policy makers, scientists, and other relevant

actors), and when alignment within the network is facilitated through regular interactions between the actors. In this framework, by considering the niche as a small network of dedicated actors, the architecture of the social network (i.e. density of relations, centrality of key actors, etc.) might result in being very relevant for the health development of the technological niche. Bearing this in mind, the thesis empirically investigates the structural characteristics of the English and Italian HFC and ADB networks by assessing the impact of FC of eco-innovating companies upon expectations' formation and learning processes (knowledge flows). On account of the lack of useful primary data to explore the relational ties among network actors, data were collected by means of an *ad hoc* designed questionnaire.

5.3.3 The identification of actors and the questionnaire administration

The first step towards the questionnaire design and administration was the identification of actors involved in the two niches.

An initial list of actors operating in the HFC niche was gathered from the national HFC associations in the two countries, i.e. the UK-HFCA for England and the H2IT for Italy. Both associations include the leading hydrogen and fuel cell companies as well as organisations from the academic community and a range of other stakeholders with an interest in clean energy solutions and the associated elements of the supply chain (from research into material science through to systems integration and distribution, the hydrogen production and storage, the hydrogen infrastructure, and other issues around the delivery, storage and use of associated fuels). The list of actors gathered from the UK-HFCA and the H2IT was then extended by identifying other actors involved in hydrogen and fuel cell research related projects in the two countries (e.g. the UK H2Mobility project for England) and not included in the original list of members. The overall number of actors identified in England was 62 (out of 72 in all the UK), of which 21 HFC producers, 14 distributors and service providers, and 27 institutional actors (i.e. governmental bodies, universities, HFC-related project partners, etc.). 59 HFC actors were identified in Italy, of which 28 are producers, 5 are distributors and service providers, and 26 are institutional

actors. Their names are listed in the questionnaires reported in Appendixes A.3 and A.4.

Similarly to the HFC niche, the list of actors operating in the ADB niche was gathered from the national ADB associations in the two countries, i.e. the ADBA (Anaerobic Digestion and Bioresources Association) for England and the CIB (Consorzio Italiano per il Biogas) for Italy. In both cases, association members span the full length of the biogas industry supply chain, from operators and anaerobic digestion plant suppliers to institutional actors (e.g. governmental bodies), universities, utilities, etc., supporting the development of merchants, on-farm and community AD, syngas from gasification, landfill gas and water treatment facilities, and the use of biogas for power, heat, transport, and injection to grid. In this case, the overall number of actors identified was 101 in England (out of 154 in all the UK), of which 82 are operators and plant suppliers and 19 are institutional actors, and 59 in Italy, of which 44 are operators and plant suppliers and 15 are institutional actors. Their names are listed in the questionnaires reported in Appendixes A.5 and A.6.

As for the regime-level investigation, the niche-level questionnaires were administered by means of the CAWI technique. After computerising the HFC and ADB questionnaires by means of the 'Qualtrics' web platform (http://www.qualtrics.com/),[35] companies were contacted telephonically to inform them about the research aims of the thesis and to identify the most appropriate person in charge within the enterprise to answer the questionnaire (director, strategic planning manager, etc.). Enterprises that agreed to participate in the survey received a web-link to the questionnaire in their inbox, giving them the possibility of filling out the questionnaire online. The CAWI technique represented the most effective way to survey companies, considering the long list of niche actors provided in the questionnaire, each of which respondents had to declare their existing type of relationship with (i.e. 'interaction', 'knowledge exchange', or 'none'). As argued in section 5.2.5, the

[35] Compared to 'Obsurvey', the 'Qualtrics' web service provided a more effective way for formatting the questionnaire for the SNA investigation.

computerised environment also allowed filtering questions in the background so that only questions relevant to the respondent appeared on their screen.

In order to validate questionnaires, the internal ‘compulsory fields’ request was adopted for almost all questions. In this way, only questionnaires that contained answers in at least all of the compulsory fields were considered complete and hence assessed for validation of responses. As for the regime-level survey; started but suspended questionnaires were considered incomplete after 45 days from the administration date and therefore they were not assessed for validation. Validation of complete questionnaires was assessed by looking at the consistency of answers in terms of reliability, the number of ‘don’t know’ answers, the role of the respondent within the enterprise and consistency in the type of relationship declared. In this way, only data from ‘valid’ questionnaires were registered and used for the empirical analysis. Both, the HFC and ADB, questionnaires were launched simultaneously in November 2014 and concluded in April 2015. A detailed description about the number of companies contacted and invited to take part in the survey, the response rate, the percentage of complete, incomplete, valid and invalid questionnaires returned will be provided in the next chapter.

5.3.4 The niche-level questionnaire explained

The questionnaire employed for investigating the HFC and the ADB niches was divided into four parts. The first collected general information about niche-level companies in terms of size, age, stage of development, drivers of EIs, and FC, by using most of the questions already employed in the regime-level questionnaire. The second gathered information on companies’ expectations about the future development of the niche as well as on companies’ degrees of knowledge about the niche in terms of technology, organisation, etc. The third collected information on networking activities and, more precisely, on the existence of ties and the kind of relationships among actors. More specifically, respondents were asked to identify, from a list of niche actors provided, those actors with whom they have established a *generic interaction* and/or an *exchange of knowledge*. Following Falcone and Sica (2015) and Morone et al.

(2015), the above set of questions allowed defining two different types of networks, i.e. (1) the '*Interaction' network* and (2) the *'Knowledge Exchange' network*. The first deals with any kind of mutual interaction, not necessarily related to HFC and ADB. In contrast, the 'Knowledge Exchange' network is more relevant when it comes to assessing the impact of the network architecture in boosting expectations' convergence and learning processes, which is necessary for a niche to develop and succeed. Finally, the fourth part concluded the questionnaire by collecting some information about the respondents (name, position within the company, etc.). The total number of questions was 14 in the HFC questionnaire and 13 in the ADB questionnaire, which represent approximately the same number of questions administrated in the regime-level questionnaire to 'innovative and also eco-innovative' companies.[36]

First part (questions 1 to 8)

After a 'welcome page' that briefly informed respondent about the aims of the questionnaire and the estimated time of completion, the first part of the questionnaire collected information about the size, age, stage of development, drivers of EIs, and FC of eco-innovating companies at the niche level. Most of the questions used were also employed in the regime-level questionnaire described in section 5.2.6. In particular:

- **Question no. 1** asked the respondents for the number of company employees. This allowed identifying the company size, which is one of the determinants of FC (section 3.4).[37] The question was composed of multiple choice single answer queries, where 'less than 10', '11-49', '50-249', '250 or more', and 'don't know' were the possible answers provided.

[36] The different total number of questions between the HFC and the ADB questionnaires was due exclusively to the organisation of actors into a different number of groups. While HFC actors were grouped into three groups (i.e. producers, distributors and service providers, and institutional actors), ADB actors were grouped into two groups only (i.e. operators and plant suppliers and institutional actors).

[37] This question was not included in the regime-level questionnaire where information about the number of employees was already provided by the FAME and the AIDA datasets employed for the identification of eco-innovating companies.

- **Questions no. 2** and **no. 3** asked year of establishment and stage of development of companies, respectively, (see questions no. 1 and 2 of the regime-level questionnaire).[38]
- **Question no. 4** dealt with the EI drivers by asking the companies how important the listed reasons were in their decision to operate in the niche (see question no. 9 of the regime-level questionnaire).
- **Question no. 5** asked about the sources of finance employed by companies (see question no. 10 of the regime-level questionnaire).
- **Question no. 6** asked enterprises how significantly they feel that financial barriers constrained their innovation activity (see questions no. 11 of the regime-level questionnaire). Answers allowed to group companies according to their level of FC. More specifically, after deriving the frequency distribution for any option provided (i.e. 1, 2, 3, and 4), companies were grouped by the WAA into the following four groups: 'not financially constrained' group when $1 \leq WAA < 1.75$, 'low financially constrained' group when $1.75 \leq WAA < 2.5$, 'medium financially constrained' group when $2.5 \leq WAA < 3.25$, and 'high financially constrained' group when $3.25 \leq WAA \leq 4$.[39]
- **Questions no. 7** and **no. 8** asked companies whether they believed that financial barriers are the same in both eco-innovative and not eco-innovative projects (see questions no. 12 and no. 13 of the regime-level questionnaire).

Second part (questions 9 and 10)

The second part of the questionnaire gathered information on companies' expectations about the future development of the niche as well as on the degree of knowledge about niche-related technology.

- **Question no. 9** investigated the expectation level of companies in terms of total replacement of the current fossil-based sociotechnical regime by asking the respondents how long they believe the full transition towards the use of only HFC/ADB will take. The question was a multiple choice with single answer queries and the answers provided were 'less than 10 years',

[38] Since the niche-level questionnaire was designed and administrated after the regime-level questionnaire, Question no. 2 provided a further possible option to respondents (i.e. 'After 2012') in order to also take into account very young companies.

[39] These thresholds were obtained by dividing the range of possible answers (from 1 to 4, i.e. 3) by the number of 4 (see also note 33 at p. 145).

'between 10 and 20 years', 'more than 20 years', and 'HFC/ADB will never permanently replace fossil fuel'. Answers allowed to group companies according to their level of expectations fell in the following 4 groups: 'high expectation level' group for those who responded 'less than 10 years', 'medium expectation level' group included responses 'between 10 and 20 years', 'low expectation level' group included responses 'more than 20 years', and 'very low expectation level' group included responses 'HFC/ADB will never permanently replace fossil fuel'.

- **Question no. 10** dealt with the degree of knowledge of companies about the niche they operate in by asking them how many meetings, round-tables, conferences, etc., about HFC/ADB they have organised or taken part in the previous three years. The question was a multiple choice with single answer queries and the answers provided were 'None', '1-2', '3-4', and '5 or more'. Respondents' answers allowed grouping companies according to their level of knowledge into the following 4 groups: 'very low knowledge level' group in cases where they answered 'None', 'low knowledge level' group in cases where they answered '1-2', 'medium knowledge level' group in cases where they answered '3-4', and 'high knowledge level' group in cases where they answered '5 or more'.

Third part (questions 11 to 12/13)

The third part of the questionnaire aimed to collect information on the types of relationships among niche actors in order to define the '*interaction'* and the *'knowledge exchange'* networks. This part started by informing respondents about the research's aim to capture the type of relations among actors involved within the HFC and ADB niches. After explaining the difference between 'generic interaction' (i.e. any kind of mutual interface among actors, not specifically restrained to HFC/ADB) and 'knowledge exchange' (i.e. the exchange of knowledge among actors specifically restrained to HFC/ADB), the questionnaire asked respondents to indicate all the actors they have interacted with, or have also exchanged knowledge with, in the previous three years, from a predefined list of actors provided in the questionnaire (see Appendix). All the questions were multiple choice; single answer queries and, for any actor from

the list provided, respondents had to select among 'only generic interaction', 'generic interaction and knowledge exchange', or 'none'.[40] In particular:

- **Question no. 11** asked respondents what kind of relationship they had with the HFC/ADB producers.
- **Question no. 12** asked respondents what kind of relationship they had with the HFC distributors and service providers (in the HFC questionnaire) or with the ADB institutional actors, utilities, and universities (in the ADB questionnaire).
- Finally, **question no. 13** (provided only in the HFC questionnaire – see note 36 at p.159) asked respondents what kind of relationship they had with the HFC institutional actors and project partners.

Fourth part (questions 13/14 and conclusions)

As for the regime-level investigation, the last part of the questionnaire aimed to identify companies surveyed and the relevant respondents before proceeding to the concluding page, which provided a text box for additional free comments on the questionnaire and thanked the respondent for collaborating. In particular, **Question no. 13** in the ADB questionnaire and **Question no. 14** in the HFC questionnaire gathered information about the company's name, respondent's name, and respondent's job position within the company in order to identify the enterprise and to assess the level of competence of the respondent.

The full questionnaire (in both its English and Italian version) is reported in the Appendix at the end of the thesis (Appendixes A.3 and A.4 for the HFC questionnaire and Appendixes A.5 and A.6 for the ADB questionnaire).

[40] It is assumed that, in order to exchange knowledge, a former generic interaction existed among actors.

6. EMPIRICAL RESULTS

6.1 Introduction

The present chapter presents the findings derived from the empirical investigation. The chapter is split into two parts. The first (section 6.2) deals with the results achieved from the regime-level investigation starting from the analysis of responses collected (section 6.3.1) before proceeding to the most relevant figures about the manufacturing companies surveyed (section 6.3.2) and the findings obtained from the econometric analysis (section 6.3.3). In contrast, the second part of the chapter (section 6.3) focuses upon the results achieved from the niche-level investigation by reporting the analysis of responses and figures about the HFC and ADB companies surveyed (section 6.2.1) and the findings obtained from the SNA in terms of architectural characteristics of the HFC and ADB niches (section 6.2.2) and in terms of the HFC and the ADB networks augmented with attributes (section 6.2.3).

6.2 Results from the regime-level investigation

6.2.1 Analysis of responses

A large number of companies reached telephonically revealed a general awareness about environmental issues and a fraction of these also had a dedicated section of their commercial website that specifically addressed their environmental commitment. However, many enterprises explicitly refused to be surveyed, never filled the questionnaire or suspended it after answering only a few questions. Despite this, the response rate was ultimately satisfactory. The targeted number of 384 valid questionnaires in each country was reached after contacting 3,152 English companies and 2,454 Italian companies and sending approximately 4,000 questionnaires in total (2,098 to English companies and 1,853 to Italian companies) (Table 19). The response rate (in relation to the number of companies telephonically contacted) was therefore equal to 12.2% in England and 15.7% in Italy, which increases to 18.3% and 20.7%, respectively, when considering the number of web-links to questionnaires sent to enterprises. Moreover, from Table 19, it is worth noting the different feedbacks received in the two countries. Although fully informed about the academic aims of the questionnaire, English companies showed greater diffidence to being surveyed and almost 32% of enterprises reached telephonically declined immediately (21.7% in Italy). However, the percentage of Italian companies that did not answer the questionnaire despite their initial availability to be surveyed was more than 45% compared to 33.7% of English enterprises.

Table 19 Regime-level questionnaire: response rates

	England	Italy
Companies invited telephonically to be surveyed in order to reach the targeted number of 384 valid questionnaires in each country	3,152	2,454
Companies that declined	1,008 (31.9%)	532 (21.7%)
Unreachable companies (no longer operating enterprises)	46 (1.5%)	69 (2.8%)
Web-link to questionnaire sent to companies that accepted to be surveyed	2,098 (66.6%)	1,853 (75.5%)
Unreturned questionnaires	708 (33.7%)	588 (31.7%)
Returned and invalid questionnaires	1,006 (47.9%)	881 (47.5%)
Returned and valid questionnaires	384 (18.3%)	384 (20.7%)

Note: the questionnaire was administrated from May 2012 to February 2013

The stratified random sampling along with the possibility of surveying the exact targeted number of companies per stratum (the latter result largely due to the use of the CAWI technique) allowed drastically reducing the risk of response bias. Indeed, the use of a relatively large number of cells (determined by industry, company size, and geographical dimension) to categorise companies with similar characteristics enabled 'containing' any bias within the cell. Despite this, a potential bias was identified in terms of companies that fully completed questionnaires compared to enterprises that answered mainly the compulsory fields only. More specifically:

- Companies that manufacture chemical, pharmaceutical, and plastic products were more likely to complete the questionnaire (in both countries) as opposed to enterprises that manufacture paper and printing products (in England) and of wearing apparel and furniture (in Italy), which generally limited their answers to the compulsory questions only.
- Smaller companies (in both countries) were more likely to respond to all questions.
- North-western English companies and central Italian companies were more accurate in filling out the questionnaire and more likely to return a fully answered questionnaire.

However, the effect of the above biases should be negligible since relevant information was also gathered from questionnaires that were not fully completed.

6.2.2 Figures and descriptive picture

General characteristics of companies surveyed and innovativeness

Figure 19 and Figure 20 report, respectively, establishment year and stage of development of companies surveyed.

Figure 19 Year established of regime-level companies surveyed (in percentage)

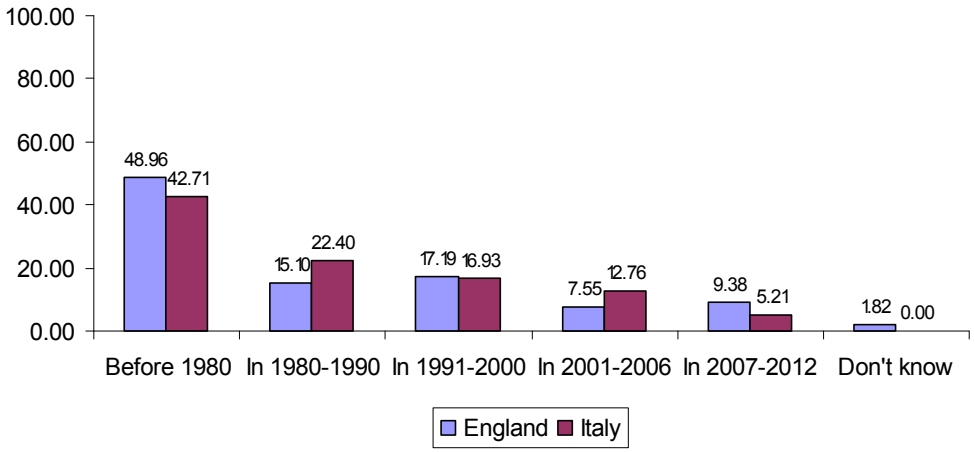
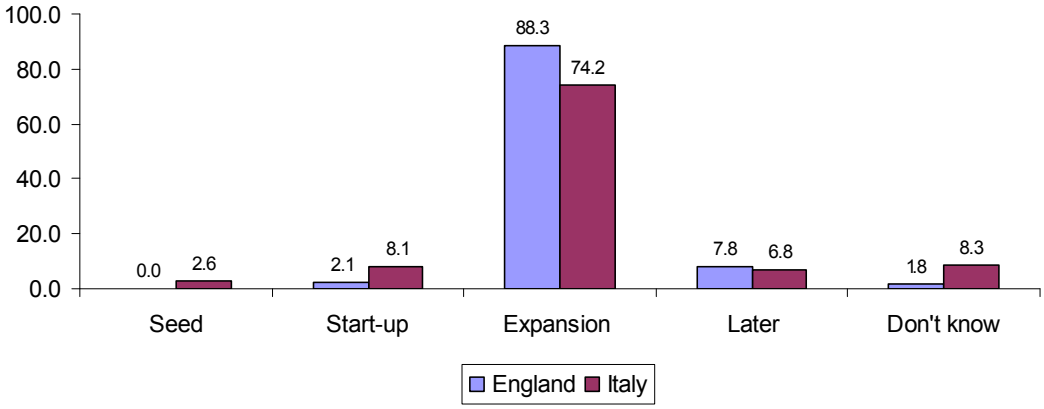


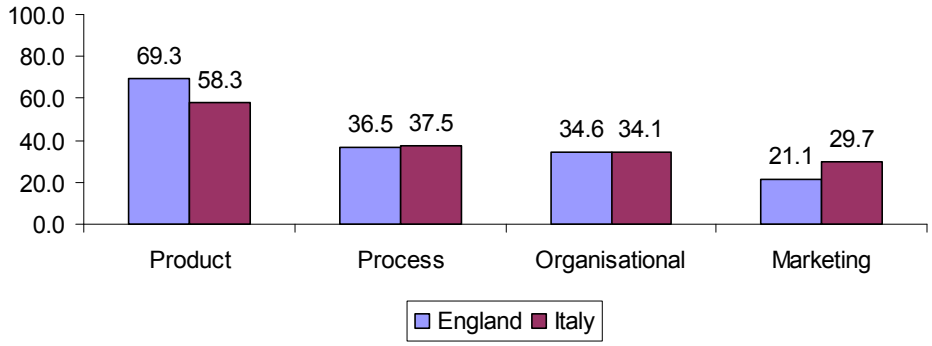
Figure 20 Stage of development of regime-level companies surveyed (in percentage)



Although most enterprises (49.0% in England and 42.7% in Italy) were established before 1980, the percentage of companies that declared to be in the expansion stage of development was very high (almost 90.0% in England and approximately 75.0% in Italy). However, it is worth noting that while there is some basis for self-reported 'seed' and 'start up' stages, the 'expansion' stage was probably subject to self-reporting error since companies are going to be generally reluctant to say that they are in a 'later stage' in their development. In this framework, the percentage of companies surveyed that declared to be

innovative in 2007-2012 was approximately the same in both countries (84.6% in England and 85.7% in Italy). In particular, the most common types of innovations introduced by the English enterprises surveyed were product innovations (69.3%), followed by process innovations (36.5%), organisational innovations (34.6%), and marketing innovations (21.1%). Similar percentages also occurred for the Italian enterprises surveyed, which introduced mostly product innovations (58.3%) followed by process (37.5 %), organisational (34.1%), and marketing innovations (29.7%) (Figure 21).

Figure 21 Innovations introduced by regime-level companies surveyed (in percentage)

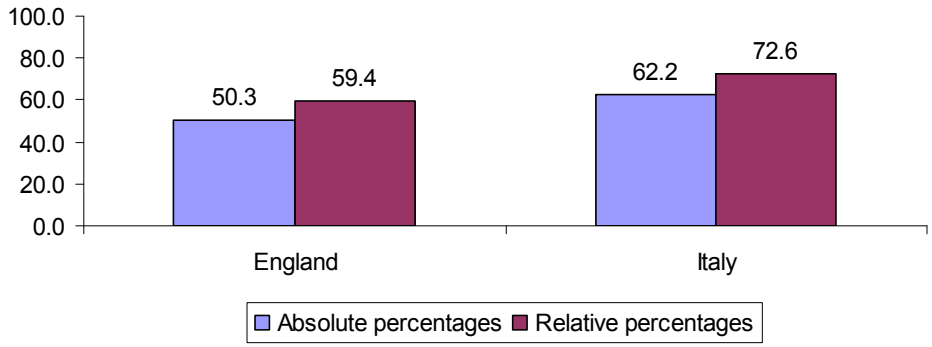


Note: each company was allowed to select more than one kind of innovation

Eco-innovativeness

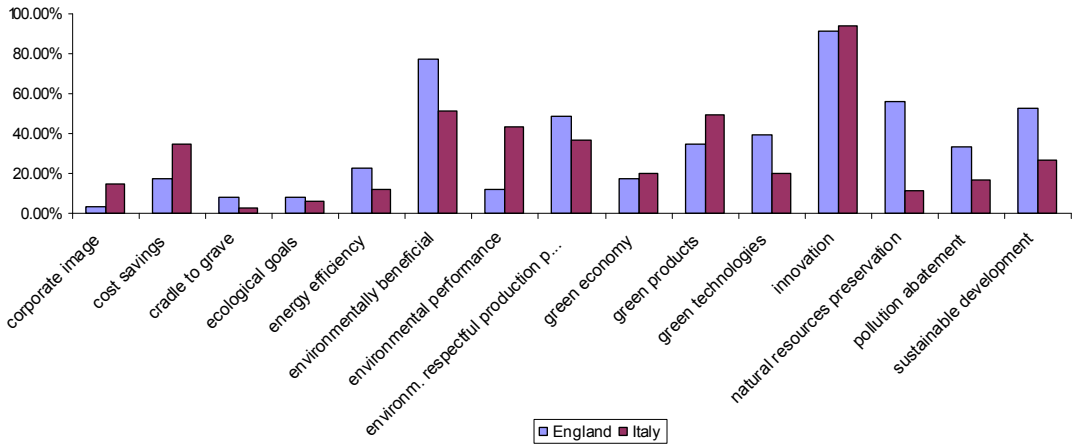
The percentage of companies that declared practicing eco-innovativeness in 2007-2012 relative to the total number of enterprises surveyed was 50.3% for England and 62.2% for Italy (absolute percentage) (Figure 22). Compared to innovative companies only, which represent 59.4% and 72.6%, respectively (relative percentage).

Figure 22 Percentage of regime-level companies surveyed that have eco-innovated (absolute and relative values)



For the reasons discussed in section 5.2.4, companies were not asked to stick to any definition of EI, but rather to define for themselves what an EI is. Answers provided by companies[41] were analysed by means of the 'QDA mining' text analysis software, which identified 15 keywords employed by enterprises to define EIs, although these appeared at different frequencies in the two countries (Figure 23).

Figure 23 Keywords employed to define EIs by regime-level companies surveyed – frequencies



Notes:
Keywords were those identified as the most frequently used words by companies to define EIs.
Only keywords whose frequency was higher than 2% are reported in the figure.

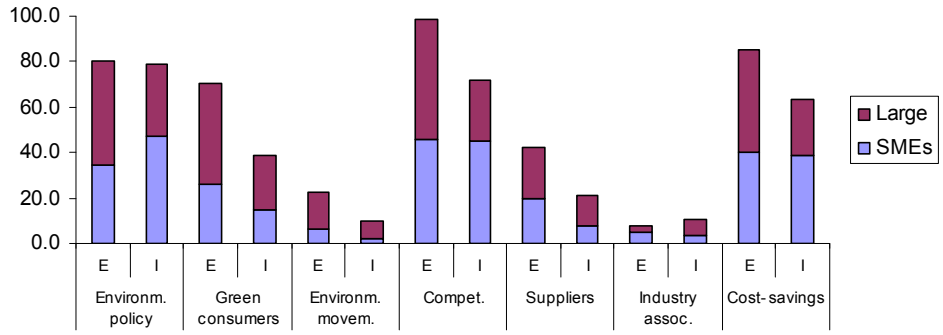
The text analysis has revealed that EIs are seen by companies as a sub-class of innovations that are beneficial to the environment by means of natural

[41] Specifically, answers to compulsory questions no. 4 ('Definition of EIs') and no. 5 ('Characteristics of EIs').

resources preservation and pollution abatement and thus contribute to environmentally sustainable pathways. Moreover, they contribute to cost-savings and energy efficiency of companies although, from the text analysis, the environmental feature of EIs definitely seems to prevail upon the economic performance. It is worth noting that companies surveyed consider EIs substantially as technological innovations (product and/or process innovations), thus excluding almost entirely the possibility that EIs also involve organisational changes (for instance to incorporate environmental perspectives into companies' operations). The analysis above, therefore, suggests that companies' viewpoints on 'who' eco-innovates differ somewhat from the conceptualisation of EI generally reported in the literature and discussed in section 2.2.

As discussed in the theoretical model presented in Chapter 4, a mix of different regime-level drivers (mainly the environmental policy, the green demand from individual consumers and environmental movements, the market competitiveness, the company suppliers, and the industry organisations) exert a certain amount of pressure upon *both the regime-level and niche-level companies*. Such external-to-company sources of pressure together with the cost-saving needs exerted from within the enterprise are supposed to drive *regime-level and niche-level* companies to eco-innovate. Within this framework, Figure 24 reports the percentage of *regime-level* companies that declared to be eco-innovative and that rated a level of importance equal to 4 ('very important') or 3 ('quite important') to each aforementioned driver. Data are organised by company size since this can also affect the eco-innovating behaviour of enterprises (see section 4.3.2).

Figure 24 Drivers of EIs for eco-innovative companies surveyed at regime-level



Notes:
- Figure reports the percentage of companies that rated a level of importance equal to 4 ('very important') or 3 ('quite important') to the different sources of pressure.
- Companies were allowed to select more than one driver

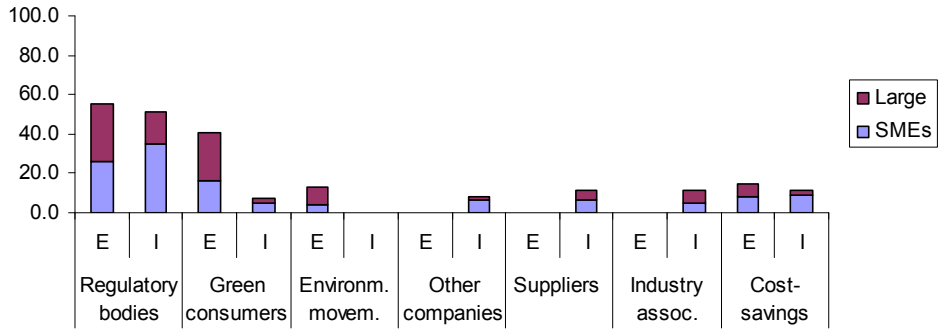
Data collected suggest that, in England, the prevailing drivers of EIs were represented by competitiveness and cost-saving pressures, which were rated 'very' or 'quite' important by 98.4% and 85.0%, respectively, of the eco-innovative enterprises surveyed. In other words, English companies (mainly large enterprises) eco-innovated predominantly to become more competitive in the market as well as a means to save production costs. As expected, the environmental policy was another relevant external driver of EIs, particularly for larger enterprises. It is worth noting that the strong pressure exerted by green consumers, companies' suppliers, and environmental movements, considered 'very' or 'quite' important were, respectively, 70.5%, 42.0%, and 22.3% of the eco-innovative enterprises surveyed. By contrast, the industry associations seem to have provided a very poor contribution in driving the eco-innovative decisions of English companies.

The most relevant driver of EIs for the Italian companies was environmental policy, which was rated as a 'very' or 'quite' important source of pressure by 79.1% of the Italian eco-innovative companies surveyed at regime-level (46.9% SMEs and 32.2% large enterprises). As for the English case, the other two most relevant sources of pressure were competitiveness and cost-saving, which were rated as 'very' or 'quite' important by 71.5% and 63.2%, respectively, of the Italian eco-innovative enterprises. Also green consumers and companies' suppliers seem to have exerted quite a significant amount of pressure upon

enterprises (mainly upon the larger ones) while the remaining sources of pressures (i.e. environmental movements and industry associations) appear to provide an insignificant or marginal role in driving the eco-innovative decisions of the Italian eco-innovative companies surveyed.

Overall, the above figures seem to provide some preliminary evidence about the existence of a mix of internal-to-company and external-to-company pressures, which have driven the eco-innovative behaviour of regime level companies, as theorised in the model presented in Chapter 4. Data from 'innovative but non-eco-innovative' companies and from entirely 'non-innovative' companies provide further evidence about the significant driving role exerted from external-to-company and internal-to-company pressures at regime level. Indeed, most non-eco-innovative and non-innovative companies surveyed did not receive any pressure to eco-innovate (Figure 25), suggesting that enterprises eco-innovate only when they are impelled by the mix of external and internal driving forces at regime level. Indeed, only two external-to-company drivers (i.e. regulatory bodies and green consumers, the latter predominantly in England) seem to have exerted some pressure upon enterprises, although such pressure was not able to drive companies to eco-innovate.

Figure 25 Pressures to eco-innovate received from 'innovative but non-eco-innovative' companies and 'non-innovative' companies surveyed at regime level



Notes:

- Figure reports the percentage of 'innovative but non-eco-innovative' companies and entirely 'non-innovative' companies that declared receiving some pressure to eco-innovate
- Companies were allowed to select more than one driver

Financial dimension

As shown in section 5.2.1 and summarised in Table 10, UK and Italy exhibit quite contrasting financial architectures. In particular, the pattern of industrial finance is market-oriented in the UK and bank-centred in Italy. This seems to be largely confirmed by the findings achieved from the regime level eco-innovative companies surveyed. Looking at Figure 26, the main sources of finance for English eco-innovative enterprises were share capital/equities (40.4%), followed by public support (34.2%), own sources (31.6%) and bank loans/advances (17.6%). A notably reduced percentage of English companies employed corporate bonds (8.8%) and private equity (3.6%) to finance their eco-innovative projects. By contrast, the weight of each source of finance employed by Italian eco-innovative enterprises was quite different from the English case. Companies surveyed declared having used mainly their own sources (56.9%) to finance their eco-innovative investments, followed by bank loans/advances (48.1%), and public support (41.0%). It is worth noting the low recourse of companies to corporate bonds (13.8%), share capital/equities (9.6%), and private equity (2.1%) to finance EIs.

Figure 26 Source of finance for eco-innovative companies surveyed at regime level

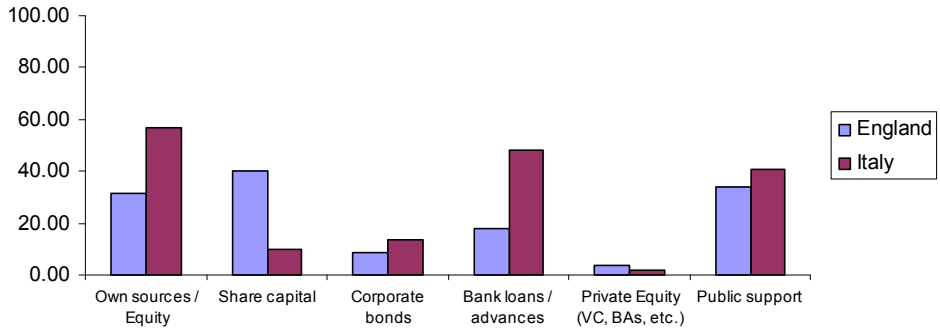


Figure 27 reports the main barriers faced by regime-level companies when seeking to finance their eco-innovative projects. More specifically, the figure reports, for any option provided, the percentage of eco-innovative companies surveyed that rated that option as ‘very’ or ‘quite’ important. Similarly, Figure 28 deals with the financial barriers faced by ‘innovative but not eco-innovative’ companies’ and by entirely ‘non-innovative’ companies, reporting, for any option provided, the percentage of enterprises surveyed that rated that option as ‘very’

or ‘quite’ important in their decision to not eco-innovate. Data are organised by company size and age since both of them can affect the extent to which companies are financially constrained (see section 3.4).

Figure 27 Financial barriers faced by eco-innovative companies surveyed at regime level, by size and age

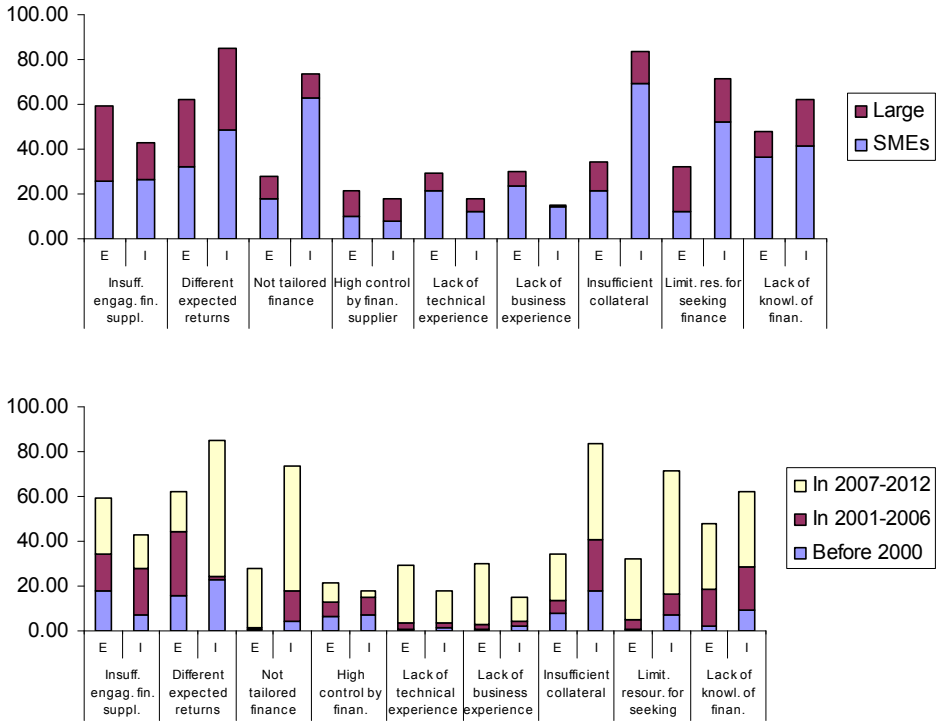
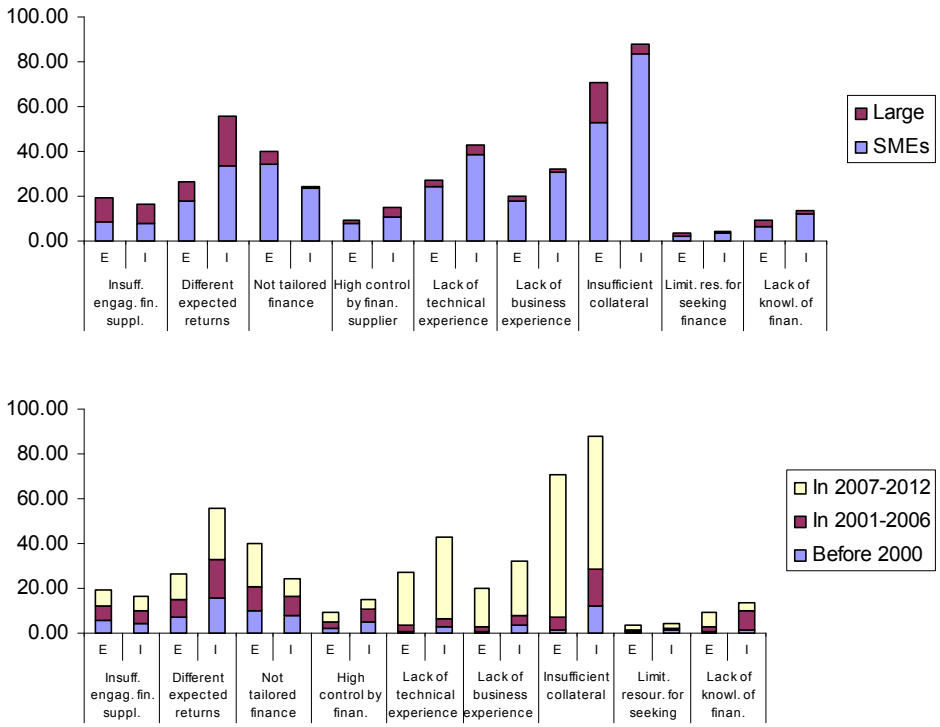


Figure 28 Financial barriers faced by 'innovative but not eco-innovative' companies and 'non-innovative' companies surveyed at regime level, by size and age



Looking at Figure 27, it can be immediately noted that most eco-innovative companies surveyed that faced financial barriers when seeking to finance their eco-innovative projects were SMEs and very young enterprises. Overall, Italian eco-innovative companies seem to have been more affected by financial problems when financing their eco-innovative projects compared to English enterprises. Moreover, the relevance of each type of financial barrier seems to differ between the two countries. In the English case, the most relevant barriers encountered by eco-innovative companies were represented by the different expected returns of financial suppliers compared to the company's business goals, which were rated as 'very' or 'quite' important barriers by 62.18% of companies.

Another very significant barrier faced by English companies was represented by potential financial suppliers insufficiently engaged with eco-innovative projects (59.07%), followed by the lack of knowledge of financing options rated as 'very' or 'quite' important barriers by 48.19% of enterprises, especially SMEs and very young companies. As argued previously, Figure 27 depicts a more problematic picture for Italian companies. As for the English enterprises, the most relevant financial barrier faced by eco-innovative companies surveyed was represented by the different expected returns of financial suppliers compared to companies' business goals, which were rated as 'very' or 'quite' important barriers by 84.94% of companies. However, other options provided were rated as 'very' or 'quite' important financial barriers by the highest percentages of Italian companies (mainly SMEs), as in the case of 'insufficient amount of collateral' (83.26%), 'finance not tailored to small-scale investment needs' (73.22%), and 'limited resources dedicated to seeking or securing finance' (71.13%).

Figure 28 depicts an interesting picture of the barriers faced by 'innovative but not eco-innovative' companies' and by completely 'non-innovative' companies. In particular, the figure reveals that the insufficient amount of collateral was the most relevant reason for companies to not eco-innovate, since it was rated as a 'very' or 'quite' important barrier by 70.68% and 87.59% of English and Italian companies, respectively. Other relevant barriers that hindered companies to eco-innovate were the different expected returns of financial suppliers

compared to companies' business goals (26.18% in England and 55.86% in Italy), finance not tailored to small-scale investment needs (40.31% of English companies), and the lack of technical expertise as perceived by financial suppliers (42.76% of Italian companies). Overall, such percentages seem to provide preliminary evidence about the significant impact that FC exert upon the decision to not eco-innovate by the regime-level companies surveyed, although this aspect will be analysed in depth in the next section.

Finally, Figure 29 and Figure 30 provide companies' viewpoints about the role of environmental reputation in seeking to finance their eco-innovative projects at regime level. In particular, Figure 29 refers to eco-innovative companies while Figure 30 to 'innovative but not eco-innovative' companies.

Figure 29 Role of environmental reputation for eco-innovative companies surveyed at regime level

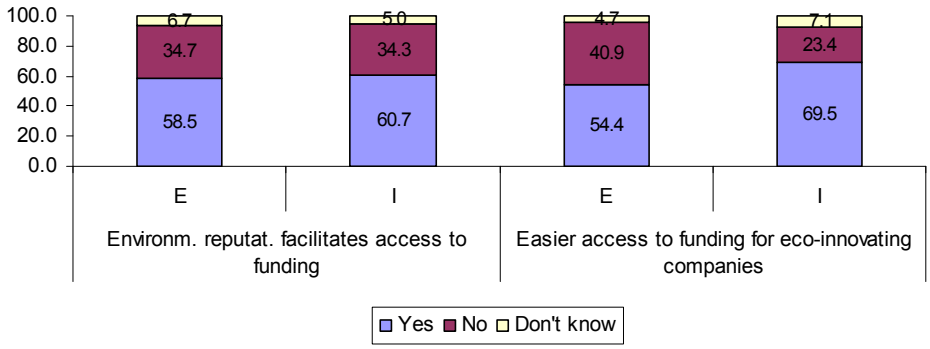
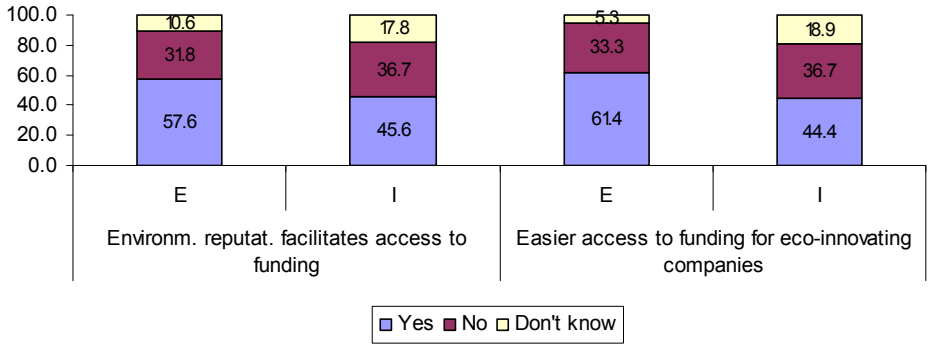


Figure 30 Role of environmental reputation for 'innovative but not eco-innovative' companies and 'non-innovative' companies surveyed at regime level



Data suggests that companies surveyed believe that the environmental reputation of enterprises can influence the possibility to gain finance and that eco-innovative companies benefit from easier access to funding. On the one

hand, such findings could support the possibility that a good environmental reputation reduces the asymmetric information of companies towards their prospective investors and the consequent FC problems discussed in section 3.3.2.5. On the other hand, this result can be due to the increasing attention of financial markets and intermediaries towards green investments that provide new financial solutions to eco-innovating enterprises. This happens, above all, in Italy where approximately 69.5% of eco-innovative companies surveyed have declared that funding eco-innovative projects is easier than other types of investments, although this seems to not prevent companies from facing financial barriers and even to be financially constrained, as shown in Figure 27 and Figure 28. In other words, although regime-level companies face a number of financial barriers in seeking to fund their eco-innovative projects and some of them seem to give up their eco-innovative investments due to financial constraints, they believe that investing in eco-innovative projects is easier than in other types of investments.

6.2.3 Econometric results

This section deals with the results achieved from the estimation of the univariate model [5.1] and the partial-recursive bivariate model [5.4] described in section 5.2.3. More specifically, the regressions estimated were:

Univariate probit regression

$$EI_i^* = Const + \delta_1 Size_i + \delta_2 Age_i + \delta_3 Sav_i + \delta_4 Env\,\mathrm{Re}\,g_i + \delta_5 Dem_i + \delta_6 Groups_i + \delta_7 Comp_i + \delta_8 Supp_i + \delta_9 IndAss_i + \delta_{10} FC_i + D_{ind} + \varepsilon_i \quad [6.1]$$

Partial-recursive bivariate probit regression

$$\begin{cases} EI_i^* = Const + \gamma_1 Size_i + \gamma_2 Age_i + \gamma_3 Sav_i + \gamma_4 Env\,\mathrm{Re}\,g_i + \\ \gamma_5 Dem_i + \gamma_6 Groups_i + \gamma_7 Comp_i + \gamma_8 Supp_i + \gamma_9 IndAss_i + \\ + \gamma_{10} FC_i + D_{ind} + u_i \\ FC_i^* = Const + \phi_1 Size_i + \phi_2 Age_i + \phi_3 Coll_i + \phi_4 Debt\_Eq_i + \\ + D_{ind} + \xi_i \end{cases} \quad [6.2]$$

In regression [6.1] the propensity of the company to eco-innovate *i* (EI_i) was regressed upon a vector of variables representing the drivers of EIs (i.e. company size, cost-saving needs, environmental regulation, customers' demand, environmentalist/consumer groups, competitors, suppliers, and industry associations) as well as upon a variable that captures the existence of FC. Moreover, a proxy for company's age along with industry dummies were added to the regressors in order to take into account their possible impact upon the propensity of companies to eco-innovate. Regression [6.2] controlled for endogeneity of the FC variable, by considering the decision to eco-innovate and the probability of becoming financially constrained as two simultaneous questions. Therefore, along with the index equation for having eco-innovative activities, an index equation for facing FC was estimated where a proxy for FC was regressed upon the determinants of FC such as a company's size, age, and industries. Moreover, a proxy for collateral and for a company's debt leverage were added to the regressors, while the comparative analysis between English and Italian companies allowed investigating the impact of FC upon the co-innovative decisions of enterprises in different countries. A detailed description of variables used is reported in Table 20. Descriptive statistics and the correlation matrix are presented, respectively, in Table 21 and Table 22.

Table 20. Econometric model - description of variables used

Variable[42]	***Description***
EI	1 if eco-innovative 0 otherwise
Size	1 if large (i.e. with 250 employees or more) 0 if SME (i.e. with less than 250 employees)
Sav	1 if received internal cost-saving pressures 0 otherwise
EnvReg	1 if received pressures from environmental regulation 0 otherwise
Dem	1 if received pressures from customers' demand 0 otherwise
Groups	1 if received pressures from environmentalists 0 otherwise
Comp	1 if received pressures from competitors 0 otherwise
Supp	1 if received pressures from suppliers 0 otherwise
IndAss	1 received pressures from industry associations 0 otherwise
FC	1 if financially constrained 0 otherwise
Age	1 if established before 2000 0 if established after 2001
Coll	Ln (tangible assets)
Debt_Eq	Ln (long term debts/company's equity)

Table 21. Descriptive statistics

Variables	*England (no. obs =384)*				*Italy (no. obs =384)*			
	Mean	*Standard Deviation*	*Min*	*Max*	*Mean*	*Standard Deviation*	*Min*	*Max*
EI	.503	.501	0	1	.594	.492	0	1
Size	.203	.403	0	1	.035	.174	0	1
Sav	.518	.500	0	1	.456	.498	0	1
EnvReg	.679	.467	0	1	.685	.465	0	1
Dem	.554	.498	0	1	.265	.442	0	1
Groups	.177	.382	0	1	.0625	.242	0	1
Comp	.495	.501	0	1	.471	.499	0	1
Supp	.211	.408	0	1	.193	.395	0	1
IndAss	.039	.194	0	1	.125	.331	0	1
FC	.811	.387	0	1	.750	.433	0	1
Age	.812	.391	0	1	.820	.384	0	1
Coll	3.02	.572	.651	14.45	2.34	.372	.018	11.96
Debt_Eq	1.27	.629	-9.20	16.18	2.46	.720	-15.23	12.01

[42] Data about size, collateral, and companies' debt leverage were gathered from the FAME dataset for English enterprises and from the AIDA dataset for Italian enterprises. Data were evaluated in 2012.

Table 22. Correlation matrix

England

	EI	*Size*	*Sav*	*EnvReg*	*Dem*	*Groups*	*Comp*	*Supp*	*IndAss*	*FC*	*Age*	*Coll*	*Debt_Eq*
EI	1												
Size	-.121	1											
Sav	.212	.167	1										
EnvReg	.141	.082	.146	1									
Dem	.167	.002	.427	.228	1								
Groups	.291	.211	.013	.213	.101	1							
Comp	.141	.133	-.131	.124	.521	.263	1						
Supp	.331	.123	.324	-.137	.022	.101	.351	1					
IndAss	.184	.005	.003	.123	.009	.211	.151	.007	1				
FC	-.150	-.139	.009	.012	.151	.005	.023	.121	.229	1			
Age	.156	.345	-.003	.014	.009	.165	.012	.251	.175	.132	1		
Coll	-.145	.213	.093	.012	.057	.131	.241	.084	.099	-.123	.111	1	
Debt_Eq	.238	.132	.169	.004	.098	.110	.239	.005	.010	-.231	.114	.210	1

Italy

	EI	*Size*	*Sav*	*EnvReg*	*Dem*	*Groups*	*Comp*	*Supp*	*IndAss*	*FC*	*Age*	*Coll*	*Debt_Eq*
EI	1												
Size	.198	1											
Sav	.034	.251	1										
EnvReg	.201	.004	.091	1									
Dem	.151	.018	.287	.091	1								
Groups	.112	.003	.223	.019	.098	1							
Comp	.108	.209	.019	.053	.001	.182	1						
Supp	.125	.092	.172	.201	.003	-.007	.182	1					
IndAss	.003	.124	-.212	.078	.002	.132	.006	.002	1				
FC	.020	-.103	.018	.134	.037	.004	.012	.083	.182	1			
Age	.121	.023	.035	.008	.013	.129	-.001	.002	.090	.023	1		
Coll	.090	.002	.028	.010	.034	.013	.234	.001	-.072	.024	-.011	1	
Debt_Eq	.034	.111	.107	.040	.134	.206	.012	.006	.028	-.023	.102	.123	1

Regressions were run by means of the Stata 12 econometric software.

Results achieved from the estimation of the univariate probit model [6.1] are presented in Table 23. Columns (1) and (3) report coefficients obtained by estimating model [6.1] *without* the FC variable and columns (2) and (4) report the coefficients when the FC variable is included in the regression. Marginal effects are reported in Table 24.

Table 23. Estimated coefficients - univariate probit model

	England		*Italy*	
	(1)	*(2)*	*(3)*	*(4)*
Size	-.015** (.071)	-.018** (.075)	.061** (.145)	.064** (.148)
Sav	.223** (.093)	.218** (.089)	.172** (.125)	.168** (.121)
EnvReg	.198** (.112)	.204** (.115)	.132** (.139)	.136** (.142)
Dem	.043* (.189)	.045* (.301)	.025 (.149)	.030 (.154)
Groups	.001 (.136)	.004 (.139)	.005 (.329)	.007 (.343)
Comp	.485 (.155)	.491 (.161)	.003 (.179)	.007 (.184)
Supp	.064 (.120)	.066 (.124)	.056 (.139)	.057 (.143)
IndAss	.009* (.150)	.011* (.357)	.035 (.148)	.038 (.154)
Age	-.004 (.234)	-.003 (.178)	.012 (.456)	.018 (.559)
FC	-	-.365** (.141)	-	-.231** (.099)
Constant	1.321*** (.123)	1.118*** (.054)	.675** (.164)	.661*** (.093)
Industry dummies	yes	yes	yes	yes
Number of companies	384	384	384	384

Notes:
Robust standard errors in parenthesis
*,**, *** indicate 10%, 5%, 1% level of significance

Table 24. Estimated marginal effects on the probability of eco-innovating – univariate probit model

	England		*Italy*	
	(1)	*(2)*	*(3)*	*(4)*
Size	-.010 (.026)	-0.12 (.031)	.027 (.061)	.028 (.068)
Sav	.189 (.052)	.158 (.039)	.139 (.078)	.134 (.072)
EnvReg	.155 (.061)	.157 (.078)	.107 (.062)	.118 (.069)
Dem	.021 (.105)	.025 (.146)	-	-
IndAss	.01 (.065)	.016 (.156)	-	-
FC	-	-141 (.057)	-	-.119 (.061)

Note:
Standard errors in parenthesis

Looking at columns (1) and (3), coefficients of Sav and EnvReg variables are both positive and significant at the 5% level, while coefficient of Size variable is significant at the 5% level and is positive in the Italian case and negative in the English case. Moreover, coefficients of Dem and IndAss variables are both statistically significant (at the 10% level) although only in the English case. Overall such results suggest that the probability of a company starting an eco-innovative project positively depends upon cost-saving needs of the enterprise, as well as upon the environmental regulation. More specifically, the probability for an English (Italian) company to be eco-innovative increases, respectively, by approximately 19% (14%), in the case of cost-saving needs, and by approximately 15% (11%) when the enterprise reacts to pressures exerted by environmental regulatory bodies. Similarly, pressures from green demands and industry associations increase the probability of companies eco-innovating by, respectively, 2% and 1%, although this happens only in the English case.

Finally, company size exerts a different impact upon the eco-innovative decisions of English and Italian enterprises: being a larger company decreases the probability of being eco-innovative in England by 1%, yet increases such probability by approximately 3% in Italy. No significant effect is exerted by the remaining variables whose coefficients are not statistically significant. When the FC variable is introduced in the regression (columns (2) and (4)), the above coefficients keep their sign and significance levels, although some marginal

effects slightly change. In particular, the probability of English (Italian) companies being eco-innovative now increases to approximately 16% (13%) in the case of cost-saving needs and to 17% (12%) in the case of environmental regulation pressures, while the probability of eco-innovating due to green demand, industry associations, and size remains approximately the same. More interestingly, the coefficient of FC variable is negative and statistically significant at the 5% level, suggesting that the presence of FC negatively affects the probability of English and Italian companies being eco-innovative: being financially constrained decreases the probability to eco-innovate by 14% in England and 12% in Italy.

Table 25 and Table 26 report, respectively, the coefficients and the marginal effects achieved from the estimation of the partial-recursive bivariate probit model [6.2].

Table 25. Estimated coefficients - partial-recursive bivariate probit model

	England		*Italy*	
	(1)	*(2)*	*(3)*	*(4)*
	Index equation for EI	*Index equation for FC*	*Index equation for EI*	*Index equation for FC*
Size	-.019** (.076)	-.093** (.043)	.071** (.156)	.069*** (.054)
Sav	.115** (.084)	-	.161** (.119)	-
EnvReg	.196** (.109)	-	.145* (.147)	-
Dem	.051 (.339)	-	.032 (.157)	-
Groups	.006 (.143)	-	.008 (.349)	-
Comp	.454 (.149)	-	.011** (.191)	-
Supp	.067 (.127)	-	.051 (.135)	-
IndAss	.022 (.571)	-	.026 (.131)	-
Age	-.008* (.301)	.039* (.090)	.012** (.321)	.030** (.142)
FC	-.391** (.149)	-	-.286** (.112)	-
Coll	-	-.240 (.098)	-	.018 (.020)
Debt_Eq	-	-.012 (.011)	-	-.039 (.056)
Constant	1.097*** (.048)	.542*** (.394)	.056*** (.076)	.022*** (.114)
Industry dummies	yes	yes	yes	yes
Rho		.431*** (.151)		.286*** (.493)
Number of companies	384	384	384	384

Notes:
Robust standard errors in parenthesis
*,**, *** indicate 10%, 5%, 1% level of significance

Table 26. Estimated marginal effects on the probability of eco-innovating – partial-recursive bivariate probit model

	England			*Italy*		
	Direct	*Indirect*	*Standard Error*	*Direct*	*Indirect*	*Standard Error*
Size	-.014	-.071	.061	.031	.053	.098
Sav	.161	-	.025	.121	-	.049
EnvReg	.146	-	.054	.123	-	.078
Comp	-	-	-	.009	-	.067
Age	.025	.031	.098	.009	.018	.487
FC	-.193	-	.061	-.172	-	.079

Results from the partial-recursive bivariate probit model broadly confirm the findings determined from the estimation of the univariate probit model. The correlation coefficient (rho), which accounts for the correlation between the residuals in each of the two probit models, is statistically significant at the 1% level in both the English and Italian cases, thus confirming that the two probit regressions can be estimated simultaneously. In particular, the coefficient of the FC variable is still negative and significant. Similarly, coefficients of Sav and EnvReg variables are still positive and significant, although the level of significance of the EnvReg variable shifts from 5% to 10% in the Italian case.

Unlike the univariate probit model estimation, coefficients of Dem and IndAss variables are not statistically significant, while the Comp variable is now significant and positive, although only in the Italian case. The Size and Age variables are significant in both index equations, although they are both negative in the English case and positive in the Italian case. Looking at the marginal effects, results suggest that, *ceteris paribus*, the existence of FC decreases the probability for an English (Italian) company to start an eco-innovative project by 19% (17%). Similarly, the probability for an English (Italian) company to eco-innovative increases by approximately 16% (12%) in the case of cost-saving needs and by approximately 15% (12%) as a consequence of pressures exerted by environmental regulatory bodies. Similarly, competitive-related pressures increase the probability of companies to eco-innovate by 0.9%, although only in the Italian case. Finally, size and age exert both a direct and indirect effect upon the probability of eco-innovating (the indirect effect is exerted by affecting the probability of companies to be financially constrained). In particular, being a larger company decreases (increases) the probability of English (Italian) enterprises to eco-innovate by 1.4% (3.1%) as a consequence of a direct effect and by 7.1% (5.3%) as a consequence of an indirect effect. Similarly, being an older company decreases (increases) the probability of English (Italian) companies to eco-innovate by 2.5% (0.9%) as a consequence of a direct effect and by 3.1% (1.8%) as a consequence of an indirect effect. No significant effect is exerted by the remaining variables whose coefficients are not statistically significant.

6.3 Results from the niche-level investigation

This section reports the empirical findings achieved from the niche-level investigation. The section is organised as follows: Section 6.3.1 discusses the response rates of the questionnaire and reports a preliminary descriptive picture about the HFC and ADB sectors in England and Italy on the basis of the results obtained from the first part of the questionnaire, thus providing a first general picture of the two niches. Sections 6.3.2 and 6.3.3 analyse the architectural features of the HFC and ADB networks in the two countries according to the results achieved from the second and third parts of the questionnaire. The analysis has been carried out at two levels: First, section 6.3.2 explores the general architecture of the HFC and ADB networks by showing their evolutions when moving from the '*interaction*' to the '*knowledge exchange*' network. Subsequently, section 6.3.3 analyses the two networks augmented by attributes. The use of FC among attributes has contributed to understanding whether or not FC affect the development and the diffusion of radical technological EIs at niche level, hindering thus the possibility for a sustainability transition to occur.

6.3.1 Analysis of responses, figures, and descriptive picture

Despite the level of intricacy of the niche-level questionnaire, it can still be considered comparable to that of the regime-level questionnaire,[43] the response of niche-level companies was definitely more satisfactory than in the regime-level investigation. Only few companies explicitly refused to be surveyed and also the number of enterprises that never answered or completed the questionnaire was absolutely limited. Overall, the response rate for the HFC investigation (in relation to the number of companies telephonically contacted) was equal to 68.6% in England and 72.7% in Italy, which increased to 80.0% and 77.4%, respectively, considering the number of web-links to questionnaires sent to enterprises (Table 27). In the case of ADB, the response rate was

[43] The niche-level questionnaire provided a long list of actors asking the respondent to provide information about the kind of relation (interaction, knowledge exchange, none) he had with each of them. However, the regime-level questionnaire asked the respondent to provide his own definition of EIs along with a description of the three main EIs developed or adopted.

79.3% in England and 70.4% in Italy (88.8% and 79.5%, respectively when considering the number of web-links to questionnaires sent to enterprises). When reached telephonically, companies were informed that they were selected amongst members of the national associations for HFC/ADB and this probably contributed to their general availability in getting surveyed. Moreover, they showed a deep interest towards the research topic under investigation and some enterprises expressly asked to view the research findings once ready.

Table 27 Niche-level questionnaire: response rates

	HFC		**ADB**	
	England	Italy	England	Italy
Companies contacted telephonically	35	33	82	44
Companies which declined	4 (11.4%)	2 (6.1%)	5 (6.1%)	3 (6.8%)
Not reachable companies	1 (2.9%)	0 (0%)	3 (3.7%)	2 (4.6)
Web-link to questionnaire sent to companies that accepted to be surveyed	30 (85.7%)	31 (93.9%)	74 (90.2%)	39 (88.6%)
Not returned questionnaires	4 (13.3%)	3 (9.7%)	6 (8.1%)	2 (5.1%)
Returned and invalid questionnaires	2 (6.7%)	4 (12.9%)	3 (4.1%)	6 (15.4%)
Returned and valid questionnaires	24 (80.0%)	24 (77.4%)	65 (88.8%)	31 (79.5%)

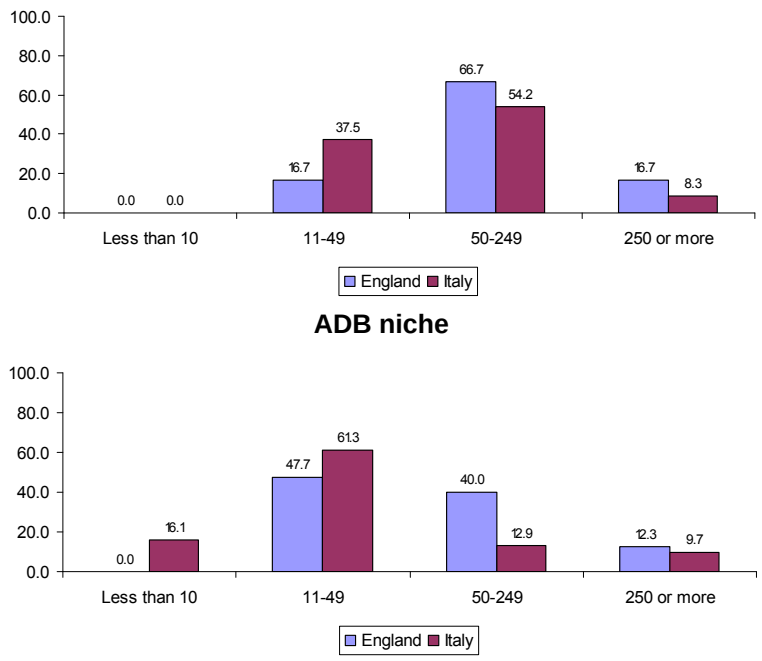
Note: the questionnaire was administrated from November 2014 to April 2015

Such high response rates drastically reduced the risk of response bias. Moreover, the questionnaire design and the use of the SNA research method allowed partially overcoming the problem of missing answers. For instance, if company A declared to have an ‘interaction’ or ‘knowledge exchange’ relationship with company B, this implies that company B also has the same kind of relationship with company A (bidirectionality). Similarly, it is assumed that the ‘knowledge exchange’ between two actors implies a former ‘interaction’ relationship among them (transitivity). In this way, it was possible to draw the general picture of the niche architecture in terms of type and number of relations among actors, despite the existence of companies that refused to be surveyed or that returned an incomplete or invalid questionnaire.

As argued earlier, answers collected from the first part of the questionnaire were essentially employed to gain figures about the eco-innovating companies

surveyed, thus allowing the development of a preliminary picture about the niches investigated. Figure 31 starts by reporting the size of the niche-level companies surveyed, organised by type of niche and country.

Figure 31 Size of niche-level companies surveyed (in percentage)

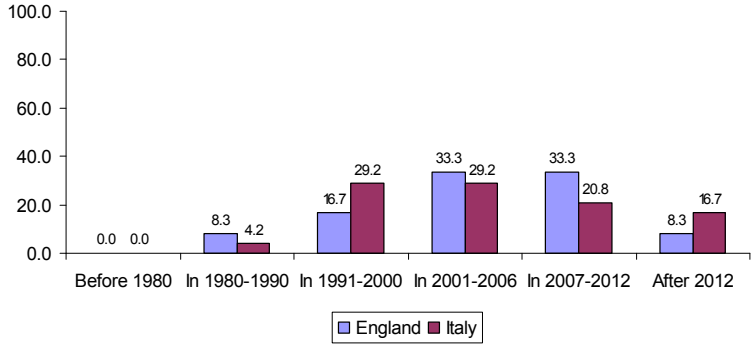


Data show that most companies are SMEs, mainly enterprises with 50 to 249 employees in the HFC niche and enterprises with 11 to 49 employees in the ADB niche. The percentage of large enterprises (with more than 250 employees) are quite limited, particularly in Italy where, by contrast, the ADB niche registers 16.1% of micro enterprises with less than 10 employees.

Figure 32 and Figure 33 report, respectively, age and stage of development of eco-innovating companies surveyed.

Figure 32 Establishment year of niche-level companies surveyed (in percentage)

HFC niche



ADB niche

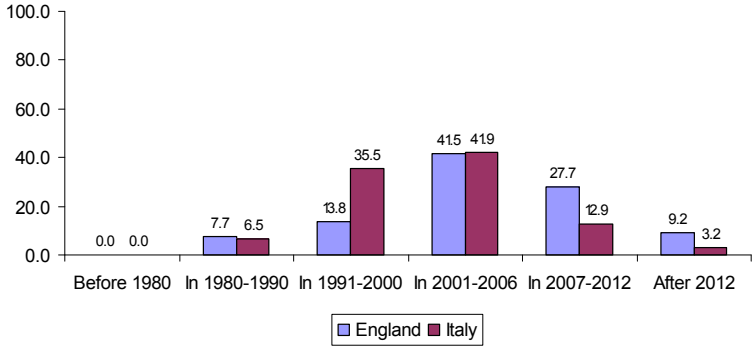
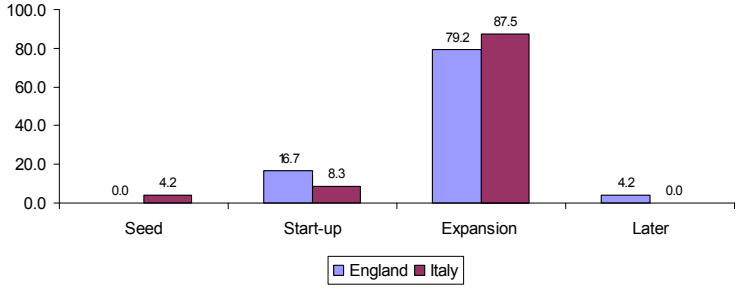
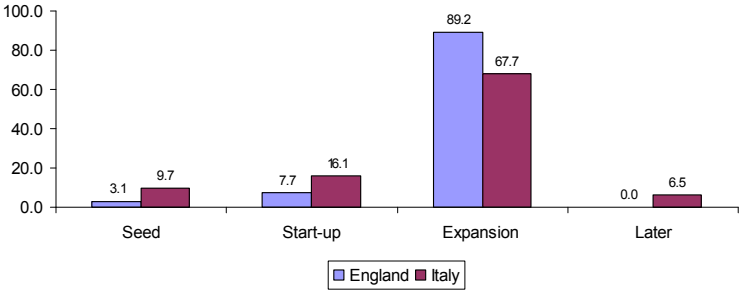


Figure 33 Stage of development of niche-level companies surveyed (in percentage)

HFC niche



ADB niche

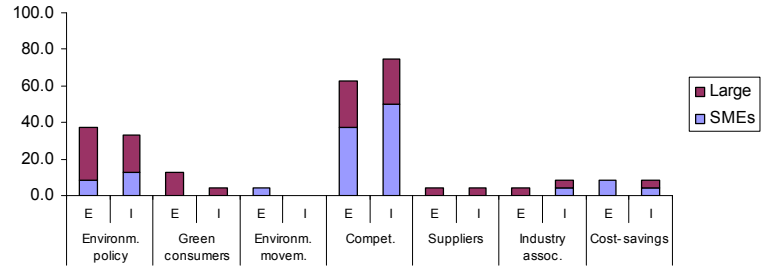


In this case, the data reveals that most companies are young, having been established in 2001-2006. However, in the HFC niche, it is worth noting the good percentage of enterprises established in 2007-2012, along with very young companies established after 2012. Moreover, most companies surveyed declared being in their 'expansion stage', although such declarations were probably subject to self-reporting error as already mentioned in section 6.2.2.

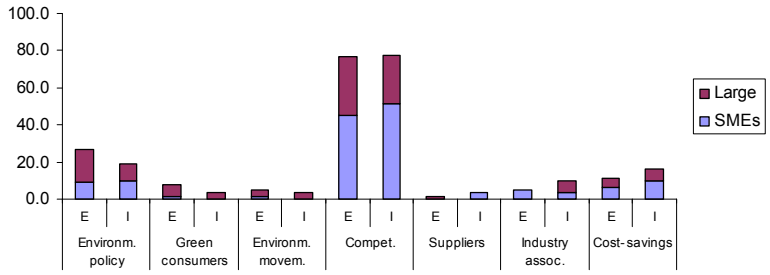
As discussed in Chapter 4, niche-level companies can be driven to eco-innovate by a mix of internal pressures (company size, cost-savings, etc.) and external pressures exerted at regime level (environmental policy, green demand from individual consumers and environmental movements, market competitiveness, company suppliers, and industry associations). Figure 34 reports the percentage of niche-level companies that rated a level of importance equal to 4 ('very important') or 3 ('quite important') to the above sources of pressure.

Figure 34 Drivers of EIs for niche-level companies surveyed

HFC niche



ADB niche



Notes:

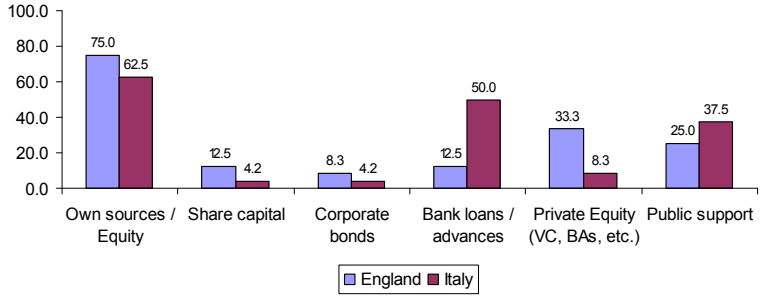
- Figure reports the percentage of companies that rated a level of importance equal to 4 ('very important') or 3 ('quite important') to the different sources of pressure.
- Companies were allowed to select more than one driver

The data collected collate a picture substantially different from that drawn in the regime-level investigation. Results suggest that, in both countries, the prevailing driver of EIs in the HFC/ADB niches is competitiveness. In other words, companies (mainly SMEs) enter the above two niches to become more competitive and to differentiate themselves from their competitors. As expected, the environmental policy is another relevant external driver of radical EIs, particularly for larger enterprises. However, the percentage of companies that declared having received ‘significant’ or ‘very significant’ pressure from the environmental policy is overall lower than in the regime-level investigation. Such a result can be attributed to the surveyed regime level companies belonging to the manufacturing sector, more than to a weaker ‘pushing force’ exerted by the environmental regulation on the niche-level companies: their core business is not necessarily related to green products or services and therefore incremental technological EIs and organisational EIs represent for them mainly a way to accomplish environmental regulations. By contrast, the development or adoption of radical EIs can be considered more as a ‘strategic’ decision for a company rather than a choice forced by environmental regulation, as suggested also by the high percentage of companies surveyed that declared entering the niche mainly to improve their competitiveness. The remaining drivers seem to have provided a very poor contribution in driving EIs, above all when compared to the regime-level case.

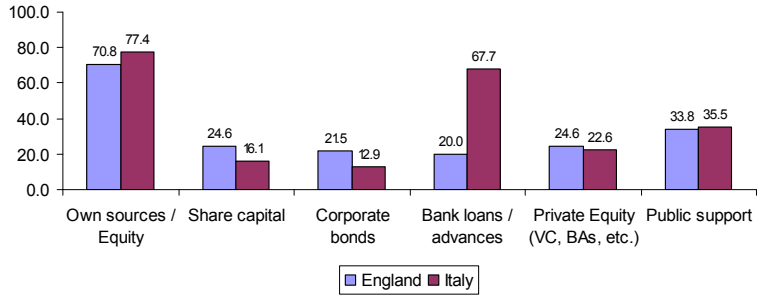
Figure 35 reports the sources of finance employed by niche-level companies to finance their eco-innovative projects.

Figure 35 Source of finance for niche-level companies surveyed

HFC niche



ADB niche



Results show that the distribution of sources of finance across the niche is approximately the same, although the same remarkable differences between the countries analysed exist. In particular, beyond their own sources/equity (which have been the main source of finance for EIs in both countries) and public support (which has represented another strong source of finance for companies surveyed), English enterprises referred to all the remaining sources of finance quite homogeneously, whereas Italian enterprises employed mainly bank loans to finance their eco-innovative projects. It is worth noting the high percentage of companies that resourced private equity in both countries, particularly in comparison to the results achieved in regards to the regime-level investigation. Such a finding is not particularly surprising considering that BA and VC are particularly useful to fund technological EIs in their early stage or expansion, when the cost of capital cannot be easily estimated, as in the case of new technologies like HFC and ADB (see section 3.3.1).

Figure 36 and Figure 37 report on the FC faced by niche-level companies when seeking to finance their eco-innovating projects. As discussed in section 3.4, the main determinants of FC stem from differences in (1) company size, (2) company age, (3) industries, and (4) FSs. For this reason, data have been

organised by company size, age, niche and country in order to take into account all of the above determinants.

Figure 36 Financial constraints faced by HFC companies surveyed by size and age

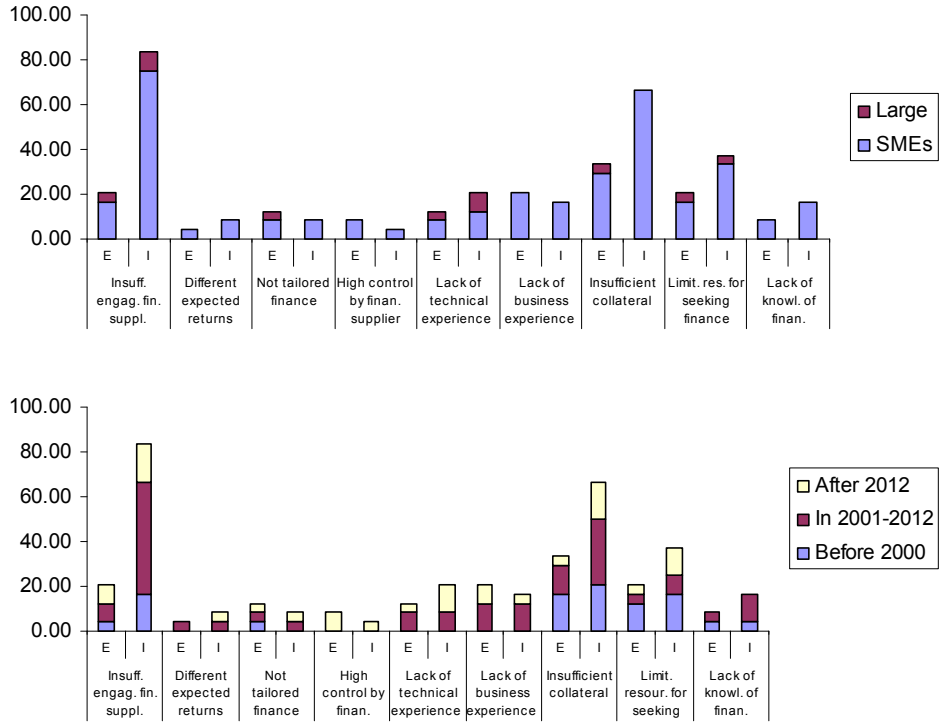
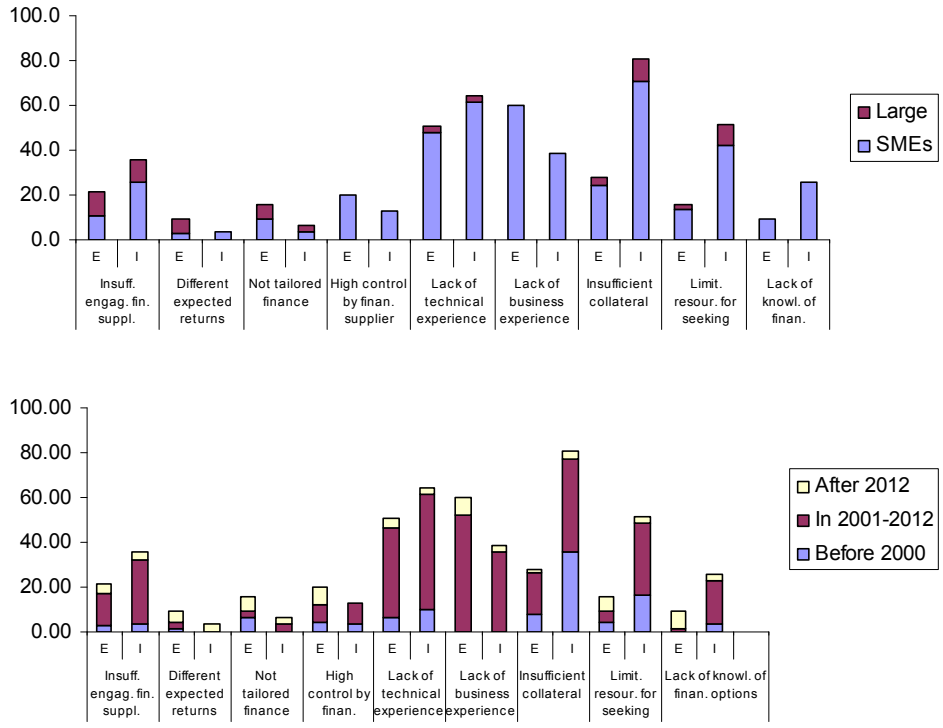


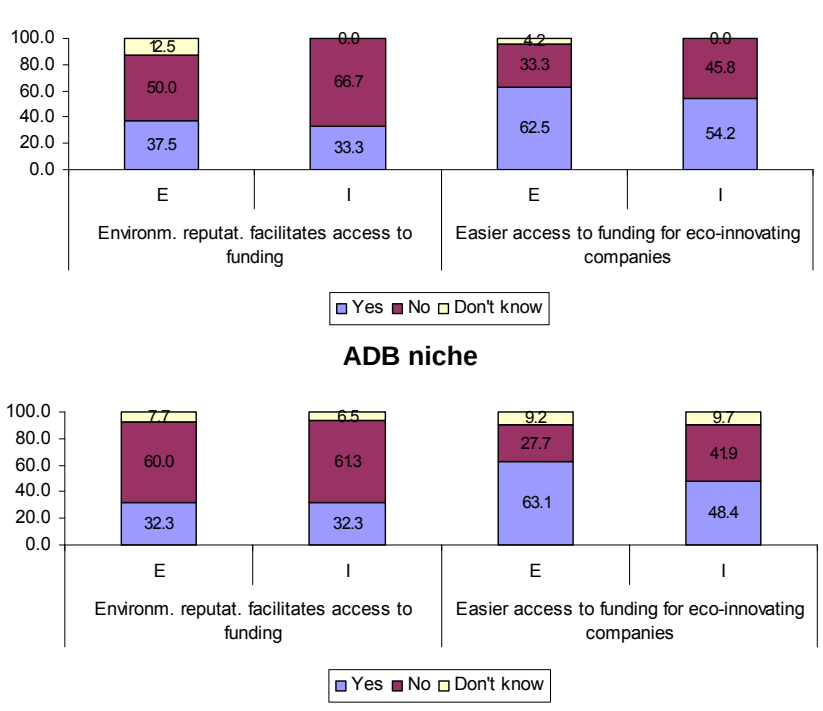
Figure 37 Financial constraints faced by ADB companies by size and age



The picture shown in Figure 36 and Figure 37 suggests that most of the financially constrained companies at niche level are represented by SMEs and very young enterprises, and that the relevance of each type of financial barrier differs across the two niches investigated. In particular, the insufficient amount of collateral, the potential financial suppliers who are insufficiently engaged with HFC/ADB projects, the lack of technical and business experience, and the limited resources in seeking financial options represent among the most relevant barriers encountered by companies in both niches, especially in the Italian case. However, companies from the ADB niche declared having faced other relevant barriers in getting financed, above all, in terms of lack of technical and business experience as perceived by prospective investors. As for the regime-level investigation, these findings seem to provide preliminary evidence about the significant impact that FC have exerted upon the eco-innovative decisions of the niche-level companies surveyed although this aspect will be investigated in depth in the next sections.

Finally, Figure 38 provides companies' viewpoints about the role of environmental reputation in seeking to finance their eco-innovative projects.

Figure 38 Role of environmental reputation for niche-level companies



Results show that environmental reputation of HFC/ADB enterprises *does not foster* their possibility of gaining finance, particularly in the Italian case (left side figure). However, from the right side figure, operating in the HFC/ADB niches could allow easier access to funding for eco-innovating companies. Therefore, findings differ partially from the regime-level investigation where companies declared that environmental reputation matters when seeking to finance eco-innovative projects. This could suggest that, in the niches analysed, environmental reputation does not reduce the asymmetric information of companies towards their prospective investors. However, as for the regime-level investigation, data could support the increasing diffusion of green investments that, together with public support (see Figure 35), provide new financial options to HFC/ADB enterprises. Such cases happen mainly in England where approximately 63.0% of companies surveyed from both niches declared that funding HFC/ADB projects is easier than other types of investments.

6.3.2 The architectural characteristics of the HFC and ADB niches

While data gathered from the first part of the questionnaire allowed drawing a preliminary descriptive analysis of eco-innovating companies involved in the HFC/ADB niches, data collected from the second and the third parts of the questionnaire were employed to run the SNA investigation. In particular, data from the third part was used to gather the general architecture of the networks investigated, while data from the second part allowed gathering attributes used to augment the original networks. To this end, data from the third part of the questionnaire was firstly organised in the form of full structural network adjacency matrices, i.e. matrices where the generic element a_{ij} is equal to 1 if a relation exists among actors i and j, and is equal to 0 if not. The 'bidirectionality' assumption (i.e. if company A has an 'interaction' or 'knowledge exchange' relationship with company B, this implies that company B has the same kind of relationship with company A) and the 'transitivity' assumption (i.e. if two companies have exchanged some knowledge, then this implies a former 'interaction' relationship among them) allow drawing a first and full picture of the architectural characteristics of the HFC and ADB networks in terms of nodes

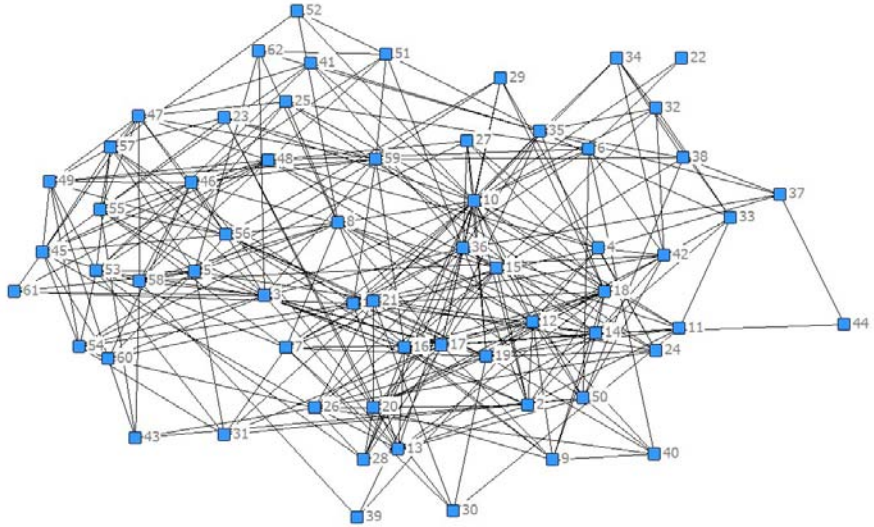
and connections despite some data initially being missing. Once organised in the adjacency matrices, data were then processed by using the ‘UCINET 6’ software package, which allowed gathering networking indexes and generating sociograms through its incorporated ‘NetDraw’ visualisation software (Table 28-Table 31 and Figure 39-Figure 42).

Table 28 The English HFC network – Networking indexes

	Density	Number of ties	Average degree	Inclusiveness
Interaction	0.16	308	9.93	100%
Knowledge exchange	0.07	143	4.61	96.7%

Figure 39 The English HCF network without attributes – sociograms

Interaction



Knowledge exchange

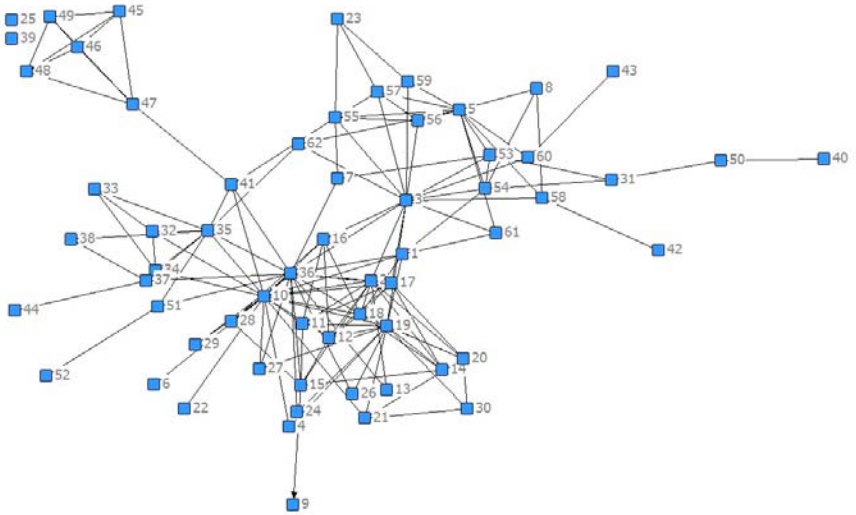
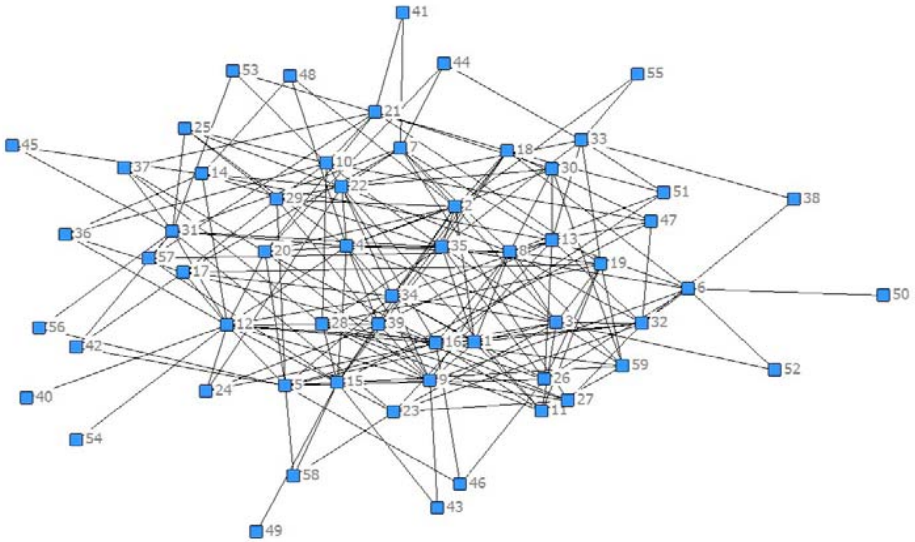


Table 29 The Italian HFC network – Networking indexes

	Density	Number of ties	Average degree	Inclusiveness
Interaction	0.12	209	7.08	100%
Knowledge exchange	0.05	89	3.02	93.2%

Figure 40 The Italian HCF network without attributes – sociograms

Interaction



Knowledge exchange

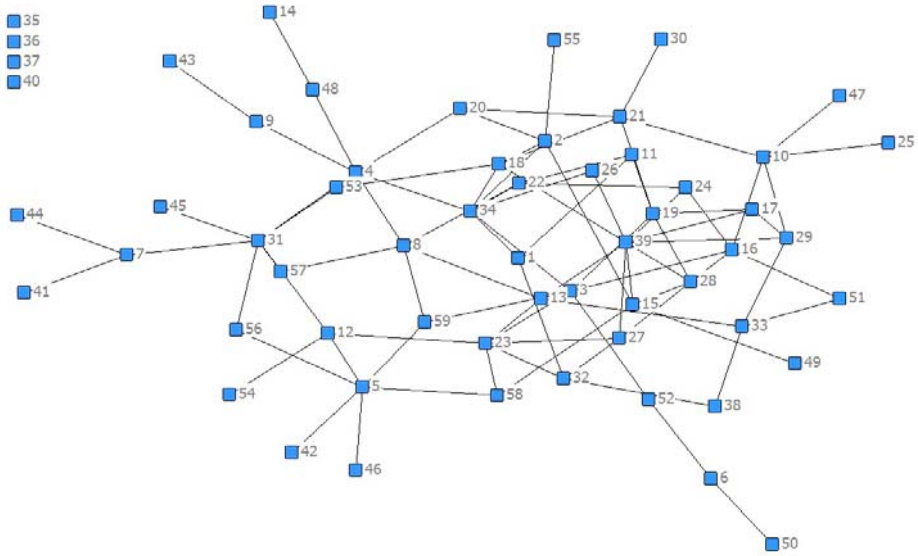
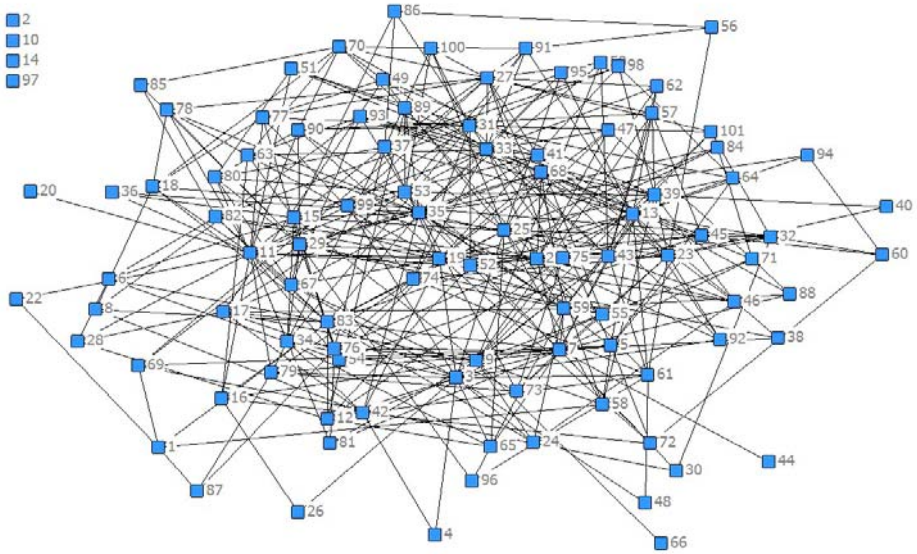


Table 30 The English ADB network – Networking indexes

	Density	Number of ties	Average degree	Inclusiveness
Interaction	0.07	380	7.52	96.0%
Knowledge exchange	0.02	125	2.48	82.2%

Figure 41 The English ADB network without attributes – Sociograms

Interaction



Knowledge exchange

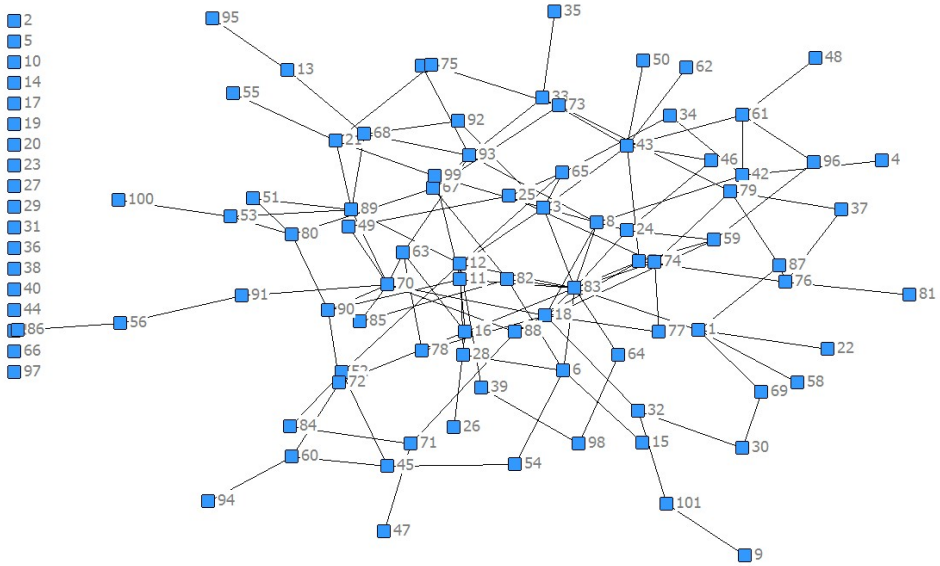
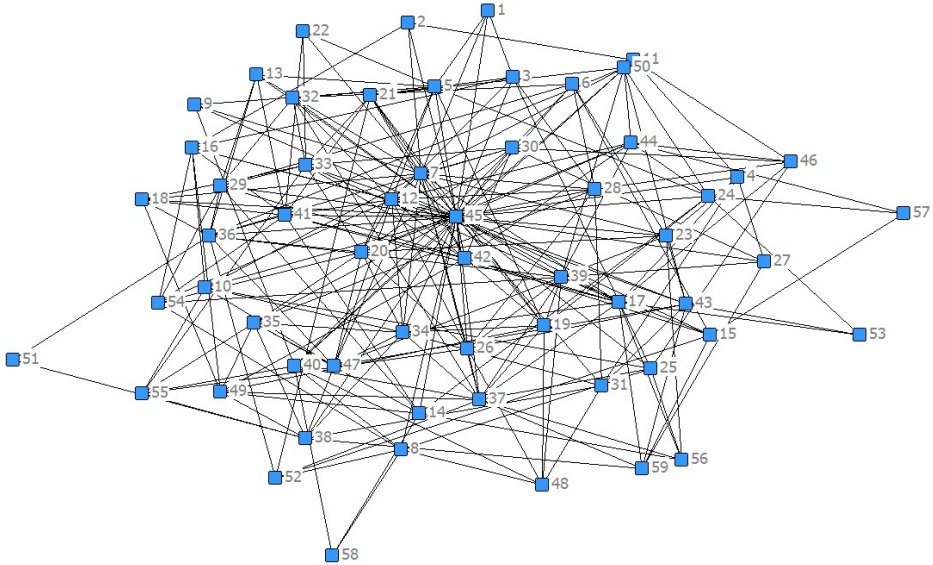


Table 31 The Italian ADB network – Networking indexes

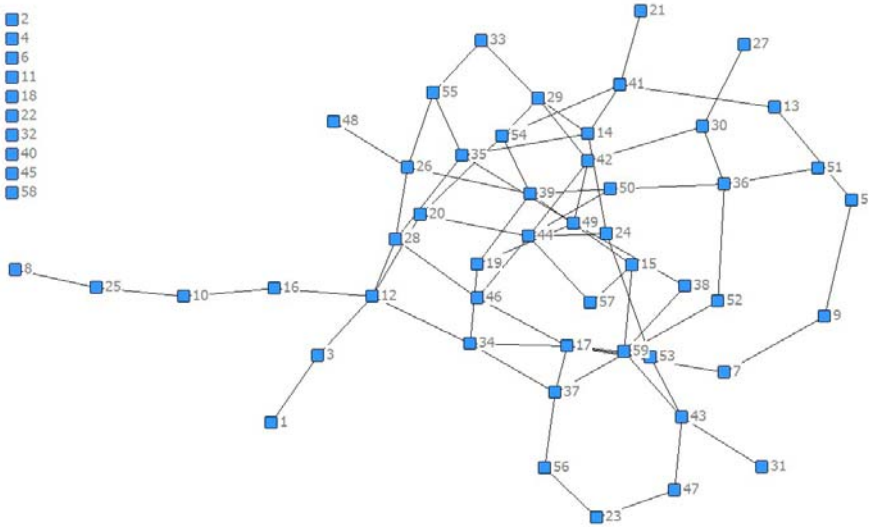
	Density	Number of ties	Average degree	Inclusiveness
Interaction	0.15	256	8.68	100%
Knowledge exchange	0.04	71	2.41	83.0%

Figure 42 The Italian ADB network without attributes– Sociograms

Interaction



Knowledge exchange



Looking at Table 28 to Table 31 and at Figure 39 to Figure 42, one can immediately notice that the network density (i.e. the portion of the *potential* connections or edges that are *actual* connections between two nodes) decreases significantly as we move from the 'interaction' to the 'knowledge exchange' network. This happens for both niches investigated and especially for the ADB network where the number of edges moves from 380 to 125 in England and from 256 to 71 in Italy, the density coefficient (i.e. the ratio of actually present edges to all possible connections)[44] moves from 0.07 to 0.02 in England and from 0.15 to 0.04 in Italy, and the average degree (i.e. the average number of direct connections that a node has)[45] moves from 7.52 to 2.48 in England and from 8.68 to 2.41 in Italy. Moreover, the inclusiveness index (i.e. the number of connected points expressed as a proportion of the total number of points) moves from 100 to 82.2% in England and from 100 to 83.0% in Italy, suggesting that some actors become isolated in the 'knowledge exchange' network and therefore do not contribute to the network density. Similar decreasing trends can be observed also for the HFC niche where the number of ties, density, average degree and inclusiveness decrease as well, moving from the 'interaction' to the 'knowledge exchange' network in both countries. Such preliminary findings seem to provide evidence that only a small portion of all the possible connections is actually used to exchange knowledge directly related to HFC/ADB production, suggesting that there is potential for a larger number of interactions that is currently unexploited in both niches.

6.3.3 The HFC and ADB niches with attributes

With consideration given to the overall picture of the HFC/ADB niches drawn in the previous section, the present section analyses the 'interaction' and the 'knowledge exchange' networks augmented with different types of attributes associated to each node of the network. As argued in section 4.3.3, the readiness of a technological niche for entering the regime and replacing the

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[44] The density coefficient is calculated as 2L/N(N-1) where L is the number of actual connections in the set and N the number of nodes. It goes from 1 (if all the potential connections are actually connections) to 0 (if there are no actual connections).
[45] The average degree is calculated as 2L /N.

current regime can be defined in terms of; (1) expectations of actors about the future development of the niche, (2) knowledge of actors in various dimensions, such as niche-related technological aspects, infrastructure requirements, organisational issues, etc., and (3) number of links among actors that characterise the social network architecture of the niche. Therefore to define niche readiness, the thesis considers the 'expectations' and 'knowledge' level attributes, having already defined the architectural characteristics of the network. In particular, due to the complexity of the HFC/ADB-related technologies, the knowledge level of companies represents a very relevant attribute to assess the niche readiness. A number of authors (see, for instance, Galliano and Nadel, 2015; Becker and Peters, 2000) argue that the company's stock of knowledge is a function of the stock of external knowledge accumulated by the company, stemming from 'industrial sources' (i.e. actors in the sector to which the company belongs to, such as suppliers and competitors) and 'non-industrial sources' (i.e. sources from scientific institutions and universities). From this point of view, beyond firms' knowledge base, a general information-sharing culture within the niche could play a key role in stimulating the knowledge exchange among niche-level actors and the learning process of companies, with particular regards to the price/performance ratio of HFC/ADB and their alignment in the socio-technical systems. Indeed, many recent studies on EIs (see, for instance, Fernando et al., 2016; Marin et al., 2015; Ghisetti et al., 2015; Horbach et al., 2013, Rave et al. 2011) have pointed out the relevance of knowledge exchange in the development of EIs, given their systemic and complex character. Such exchange can include multiple dimensions of knowledge (e.g. technology, production, policies and regulations, user preferences, infrastructure) and can originate from information-sharing contexts such as conferences, round tables, etc. or from formal cooperation agreements among actors. In the first case, the exchange is generally limited to ideas and experiences about HFC/ADB, due to the companies' concern about the possibility that opportunistic behaviours (transaction risks) occur when they release their knowledge resources outside the firm (Kim et al., 2012). In contrast, formal agreements among actors (including suppliers, universities, etc.) allow for a deeper level of knowledge and know-how exchange, such as skills and intellectual property related to HFC/ADB sectors.

The ‘expectations’ and ‘knowledge’ attributes were determined from responses given to the second part of the niche-level questionnaire (Questions no. 9 and 10). In particular, Question no. 9 allowed ranking eco-innovating companies into four different groups according to their level of expectations about the future development of the HFC/ADB niche (i.e. ‘very low’, ‘low’, ‘medium’, and ‘high’ expectation level). Similarly, Question no. 10 allowed ranking companies according to their level of knowledge about the niche into four different groups (i.e. ‘very low’, ‘low’, ‘medium’, and ‘high’ knowledge level).

Finally, the thesis considers a third and crucial attribute; namely the ‘FC’ level of eco-innovating companies, in order to investigate to what extent this also contributes to hindering the niche readiness. This attribute was gathered from Question no. 6, included in the first part of the niche-level questionnaire, which asked enterprises how significantly they felt that financial barriers constrained their innovation activity, thus allowing to rank companies into four groups (i.e. ‘not financially constrained’, ‘low financially constrained’, ‘medium financially constrained’, and ‘high financially constrained’). Table 32 reports the frequency distribution of attributes for both niches investigated.

Table 32 Attributes frequency distribution (absolute and percentage values)

	Expectations about the future development of the HFC niche	Knowledge about the HFC niche-related technology	FC
		English HFC niche	
Very low	12 (50.0%)	15 (62.5%)	3 (12.5%)
Low	7 (29.2%)	6 (25.0%)	5 (20.8%)
Medium	3 (12.5%)	2 (8.3%)	4 (16.7%)
High	2 (8.3%)	1 (4.2%)	12 (50.0%)
		Italian HFC niche	
Very low	12 (50.0%)	13 (54.2%)	7 (29.2%)
Low	8 (33.3%)	4 (16.7%)	4 (16.7%)
Medium	1 (4.2%)	3 (12.5%)	5 (20.8%)
High	3 (12.5%)	4 (16.7%)	8 (33.3%)
		English ADB niche	
Very low	13 (20.0%)	22 (33.8%)	11 (16.9%)
Low	41 (63.1%)	26 (40.0%)	17 (26.2%)
Medium	7 (10.8%)	9 (13.8%)	17 (26.2%)
High	4 (6.2%)	8 (12.3%)	20 (30.8%)
		Italian ADB niche	
Very low	4 (12.9%)	4 (12.9%)	4 (12.9%)
Low	3 (9.7%)	5 (16.1%)	8 (25.8%)
Medium	16 (51.6%)	10 (32.3%)	6 (19.4%)
High	8 (25.8%)	12 (38.7%)	13 (41.9%)

Note:
TOT of absolute vales for each column amounts to the number of valid questionnaires collected (24 for the English and Italian HFC niches, 65 for the English ADB niche, and 31 for the Italian ADB niche).

The frequency distribution of attributes reported in Table 32 provides some preliminary, but nonetheless interesting, information about the niches. In particular, the English and Italian HFC actors seem to exhibit, at the moment, a very low level of expectation about the future development of the niche, other than a very low level of knowledge about niche-related aspects (technology, infrastructure, organisational issues, etc.). Such a finding is not particularly surprising, particularly in the Italian case, where the HFC niche still represents a thin and fragile sector at its early stage of development, as discussed in section 5.3.1.1. A partially different picture emerges from the ADB niche. In particular, while in England the prevailing level of expectations and knowledge is low or very low, in Italy actors exhibit medium expectations about the future

development of the niche and a medium-high level of knowledge about the ADB related aspects.

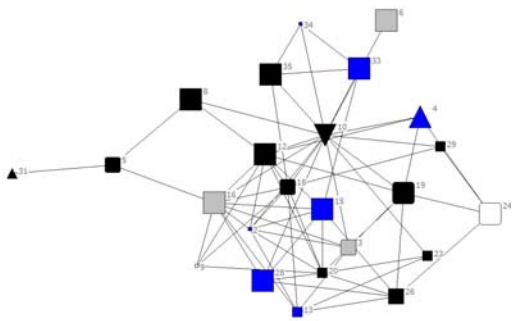
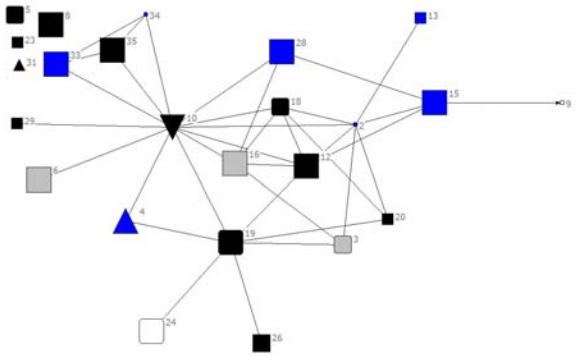
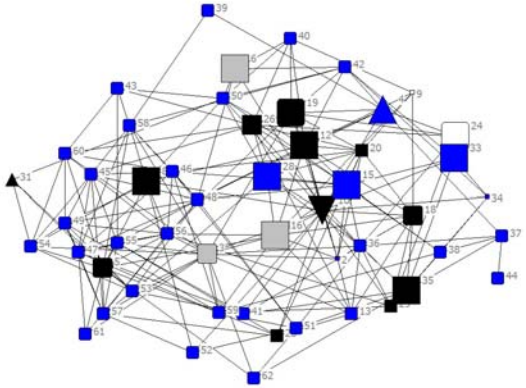
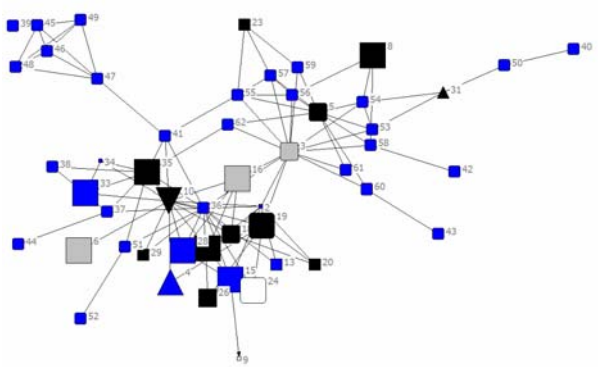
By contrast, the prevailing level of FC is generally high for all eco-innovating companies surveyed in both countries. A slightly better situation can be noted only in the English ADB niche where 11 out of 65 actors (16.9%) declared not being financially constrained and 17 out of 65 (26.2%) declared being only financially constrained to a low limit. Although the frequency distribution of the above three attributes provides some useful insights about the level of niche readiness, the last can be better assessed by looking at the architectural characteristics of the attribute augmented sociograms, as reported in Figure 43 to Figure 46. These figures identify attributes with different combinations of colour, shape, and size. In particular, colour represents the level of expectations (black = very low, blue = low, grey = medium, and white high), shape represents the level of knowledge (square = very low, rounded square = low, up triangle = medium, and down triangle = high), and finally size represents the level of FC (the larger size, the more eco-innovating had been constrained). It is worth noting that while sociograms in Figure 39 to Figure 42 (discussed in the previous section) report the architectural characteristics of *full* networks, sociograms reported in Figure 43 to Figure 46 are limited to eco-innovating companies that returned a complete and valid questionnaire.

In other words, while the ‘bidirectionality’ and ‘transitivity’ assumptions allowed gathering information about the ‘interaction’ and ‘knowledge’ exchange relations for those actors that did not return a complete and valid questionnaire (allowing thus to draw the sociograms for the full network), they could not be exploited to contribute towards the attribute augmented sociograms where attributes were achieved from a set of *direct* questions addressed to companies and therefore not achievable *ex post*. More specifically, Figure 43 to Figure 46 report two different sociograms for any network investigated. The first includes exclusively eco-innovating companies that provided a valid questionnaire. The second extends the network by also including institutional actors. Since the latter were not surveyed, they were provided with a default ‘low’ value in all the attributes considered. In this way it was possible to investigate the position of eco-

innovating companies within the almost full network (missing only companies that did not return a valid questionnaire), while at the same time keeping the focus of analysis upon eco-innovating companies.[46]

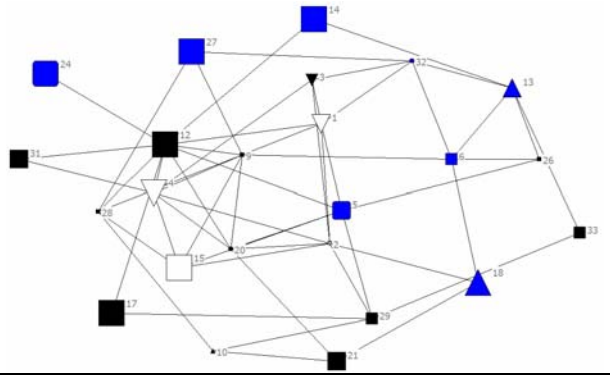
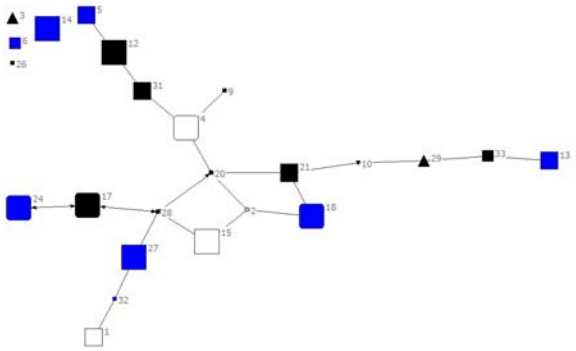
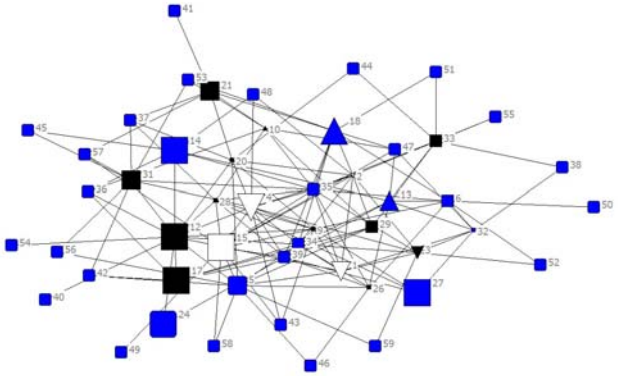
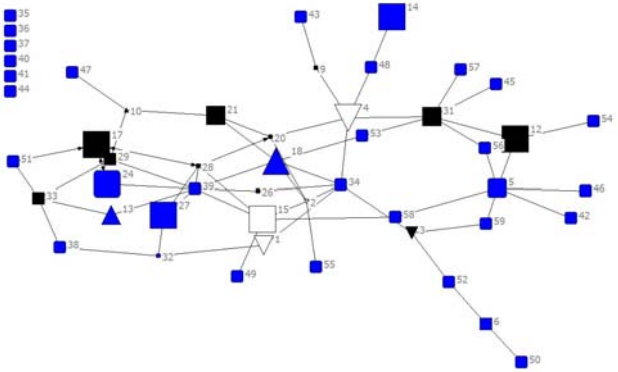
[46] Institutional actors were included exclusively to investigate the position - within the network - of companies surveyed that returned a valid questionnaire. Therefore, results do not change when institutional actors are provided with a different value (e.g. 'medium') in the attributes. However, providing institutional actors with a 'low' value in all attributes allowed better identifying the position of companies in the network.

Figure 43 The English HFC network with attributes – Sociograms

Interaction	Knowledge exchange
A	**B**
	
C	**D**
	

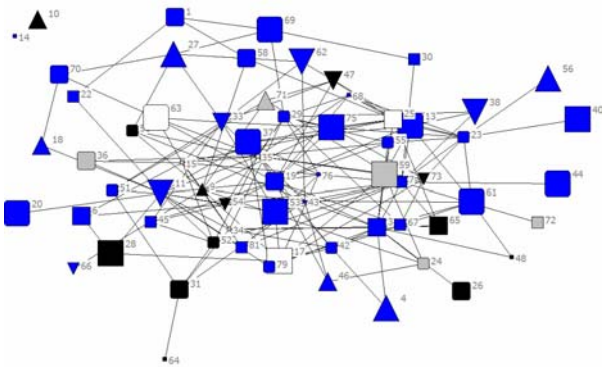
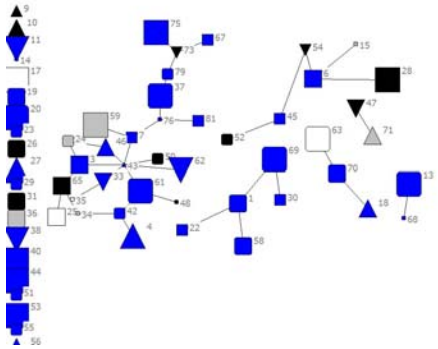
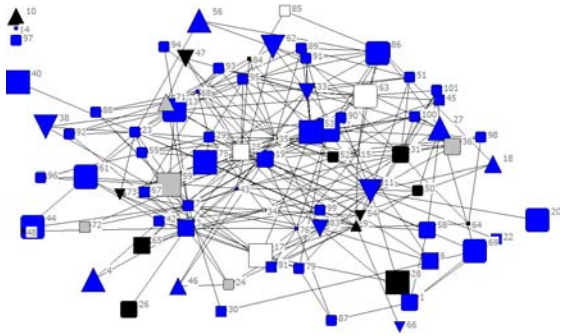
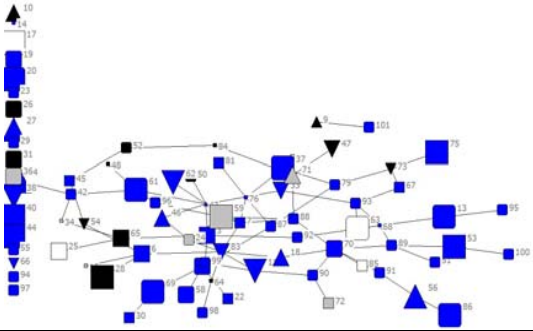
Legend and notes:
Colour represents **expectations** (black = very low, blue = low, grey = medium, white = high).
Shape represents **knowledge** (square = very low, rounded square = low, up triangle = medium, down triangle = high).
Size represents **FC** (the larger size, the more constraints).
A & B networks include only HFC producers and distributors/service providers that returned a complete and valid questionnaire.
C & D networks include only HFC producers and distributors/service providers that returned a complete and valid questionnaire along with institutional actors/project partners who were not surveyed and therefore provided with a default 'low' value in all the attributes.

Figure 44 The Italian HFC network with attributes – Sociograms

Interaction	Knowledge exchange
A	**B**
	
C	**D**
	

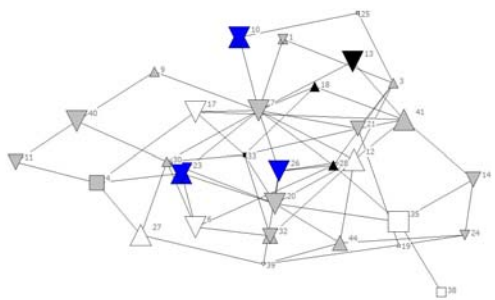
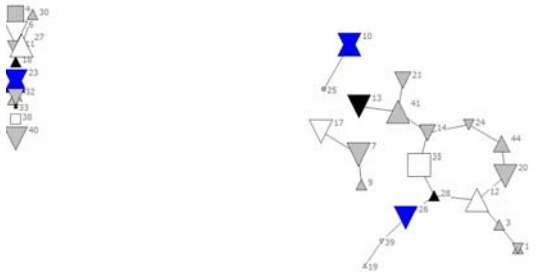
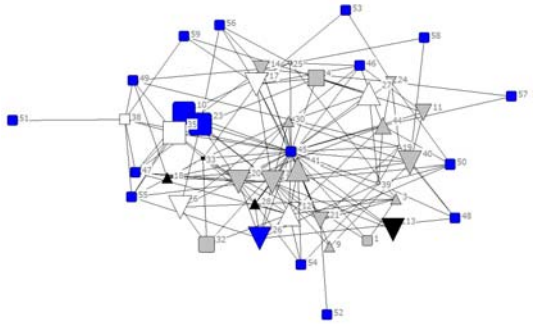
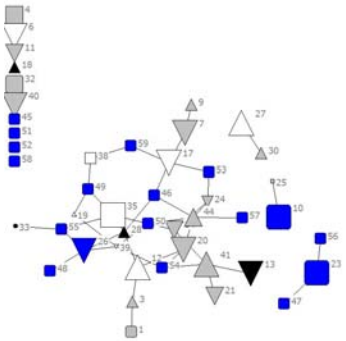
Legend and notes:
Colour represents expectations (black = very low, blue = low, grey = medium, white = high).
Shape represents knowledge (square = very low, rounded square = low, up triangle = medium, down triangle = high).
Size represents FC (the larger size, the more constraints).
A & B networks include only HFC producers and distributors/service providers that returned a complete and valid questionnaire.
C & D networks include only HFC producers and distributors/service providers that returned a complete and valid questionnaire along with institutional actors/project partners who were not surveyed and therefore provided with a default 'low' value in all the attributes.

Figure 45 The English ADB network with attributes – Sociograms

Interaction	Knowledge exchange
A	B
	
C	D
	

Legend and notes:
Colour represents expectations (black = very low, blue = low, grey = medium, white = high).
Shape represents knowledge (square = very low, rounded square = low, up triangle = medium, down triangle = high).
Size represents FC (the larger size, the more constraints).
A & B networks include only ADB operators/plant suppliers that returned a complete and valid questionnaire.
C & D networks include only ADB operators/plant suppliers that returned a complete and valid questionnaire along with institutional actors/utilities/universities who were not surveyed and therefore provided with a default 'low' value in all the attributes

Figure 46 The Italian ADB network with attributes – Sociograms

Interaction	Knowledge exchange
A	**B**
	
C	**D**
	

Legend and notes:
Colour represents expectations (black = very low, blue = low, grey = medium, white = high).
Shape represents knowledge (square = very low, rounded square = low, up triangle = medium, down triangle = high).
Size represents FC (the larger size, the more constraints).
A & B networks include only ADB operators/plant suppliers that returned a complete and valid questionnaire.
C & D networks include only ADB operators/plant suppliers that returned a complete and valid questionnaire along with institutional actors/utilities/universities who were not surveyed and therefore provided with a default 'low' value in all the attributes.

Looking at the English HFC niche limited to those companies surveyed (Figure 43 – A and B), it is possible to observe that the ‘bigger’ actors (i.e. the more financially constrained companies) are mainly ‘square’ and ‘rounded square’ actors (i.e. companies with a ‘very low’ or ‘low’ level of knowledge about the niche). By contrast, there is no specific relationship apparent between the FC level and the expectations about the future development of the niche, the ‘bigger’ actors being characterised by different colours. In other words, results seem to suggest that the more financially constrained enterprises are also companies with a low level of knowledge about the niche-related aspects, independent from their expectation level. Unfortunately, the SNA does not allow establishing a causal relationship between FC and knowledge (i.e. what causes what). In other words, it does not help to define whether FC discourage companies from acquiring new knowledge about the niche or whether low levels of knowledge make enterprises more financially constrained (for instance because of their limited information about the possible funding options).

Adjusting the analysis focus to include the niche’s institutional actors (Figure 43 – C and D), it is worth noting the different shape between the ‘interaction’ and the ‘knowledge exchange’ networks, the first being more clustered and the second being composed of three main sub-networks. Despite this, it is possible to observe, in both cases, the prevalent presence of dark (black and blue) and squared and rounded squared actors all over the networks, i.e. the widespread diffusion of actors with low knowledge and expectations. Moreover, the majority of financially constrained companies occupy central positions in the networks and hence most of the ‘interaction’ and ‘knowledge exchange’ among actors depends upon them. In the ‘knowledge exchange’ network, a medium financially constrained company (no. 3) seems to also play a significant role in connecting two out of three sub-networks. Overall, these findings draw quite a problematic picture of the English HFC niche, which does not look yet ready to enter the current fossil-fuel-based regime given the large presence of actors with a low level of knowledge and expectations. Moreover, the networking activity of actors can be jeopardised by the existence of many central-to-the-network companies with high FC. Such companies are prevented from funding all their desired

investments and this can seriously hinder the interaction activity of actors as well as the channelling of knowledge flows.

Compared to the English case, the Italian HFC networks limited to the companies surveyed (Figure 44 – A and B) look definitely less clustered. Moreover, financially constrained enterprises ('bigger' actors) are now associated not only to a low level of knowledge about the niche ('square' and 'rounded square' actors) but also to a low expectation level about the future development of the HFC sector ('black' and 'blue' actors). In other words, most financially constrained companies in the Italian HFC niche seem to be characterised by low levels of knowledge and expectation about the future development of the niche. However, as argued earlier, the SNA does not allow defining a causal relationship among attributes. For instance, we cannot infer to what extent these two attributes are affected by companies' FC and we cannot establish whether a low level of knowledge implies that companies also have low levels of expectation about the future development of the niche or whether low expectations drive companies to acquire less knowledge about niche-related aspects. The analysis of the niche extended to institutional actors (Figure 44 – C and D), reveals a partially different story compared to the English HFC network. The presence of a 'white' and 'down triangle' shaped actor occupying a central position in the 'interaction' network (i.e. company no. 4) suggests that most of the interaction activity of actors is channelled by means of an enterprise with high levels of knowledge and expectations. However, the significant role of networking played by this company can be potentially neutralised by its high level of FC, being a bigger sized actor i.e. a highly financially constrained enterprise. On the other hand, the 'knowledge exchange' network reveals the large presence of actors with low knowledge and expectations all over the network, although it lacks central actors to channel the knowledge flow among actors. This represents quite a positive finding since the potential exit of companies due to their FC could have a very limited impact on the Italian HFC niche, not fully jeopardising the networking activity of actors in terms of knowledge exchange. Summing up, findings suggest that, such as for the English case, the Italian HFC niche does not appear sufficiently mature to enter and replace the current regime, given the large presence of companies

exhibiting low levels of knowledge and expectations. However, the FC of niche-level companies seem to affect mainly the networking activity of enterprises in terms of interaction relationships among actors rather than in terms of knowledge exchange.

A partially different picture emerges from the English ADB niche (Figure 45 – A and B). In this case, the widespread low level of knowledge (square and rounded square actors) is associated not only to a high level of FC (bigger sized actors) but also to a slightly improved level of expectation of companies compared to the English HFC niche, as indicated by the large prevalence of blue over black actors within both networks. Moreover, moving from the 'interaction' to the 'knowledge exchange' network, two main findings can be noticed. The first is that many companies are now out of the network: they still interact with other enterprises but do not contribute to the network development in terms of knowledge exchange. Nevertheless, most of these 'misplaced' resources are bigger in size, blue, and square/rounded square actors (i.e. companies with high FC and low levels of expectations and knowledge) whose contribution to the knowledge exchange would have been anyway limited.

The second is the existence of small and independent sub-networks composed of a limited number of companies that exchange knowledge among themselves. It is worth noting that, in any sub-network, at least a company is highly financially constrained. When the institutional actors are taken into account (Figure 45 C and D), it can be observed that financially constrained companies are dispersed all over the networks, suggesting that the potential exit of companies due to their FC could have a more limited impact on the networking activity of English ADB companies than in the case of the HFC niche. Moreover, the sub-networks composing the 'knowledge exchange' network are now connected with each other, thus highlighting the crucial role played by institutional actors in keeping the ADB network more clustered. Although the overall findings seem to draw a somewhat less problematic picture than in the HFC niche, the English ADB network appears insufficiently mature to enter and replace the current fossil-fuel based regime. Indeed, despite the level of expectations about the future development of the niche being slightly higher

than in the HFC case, the niche readiness seems to be jeopardised by the large presence of actors with a low level of knowledge about niche-related aspects. The widespread presence of FC affecting both central and peripheral enterprises suggests that the possible exit of some financially constrained companies from the niche should not hinder the networking activity of the remaining enterprises neither in terms of interaction nor in terms of knowledge exchange. However, the latter is critically dependent upon the presence of institutional actors that play the important role of channelling the knowledge flow among the different sub-networks of companies.

Finally, turning the analysis to the Italian ADB niche, two characteristics can be immediately observed from Figure 46 A and B. The first is the massive presence of grey and triangle-shaped actors all over the networks, which suggests that companies have medium expectations about the future development of the Italian ADB niche as well as medium-high knowledge about the niche-related aspects. The second is the different shape between the ‘interaction’ and the ‘knowledge exchange’ networks, the first being more clustered and with some well recognisable central actors, while the second being characterised by the presence of different small sub-networks other than by the existence of many out-of-the-network financially constrained companies.

When the institutional actors are disregarded, it is possible to note that the Italian ADB association (actor no. 45) gains a very central position in the ‘interaction’ network, suggesting its significant role in channelling the interaction activity of niche actors (Figure 46 C). Together with the national ADB association, at least three financially constrained companies can be identified at the core of the network with the consequence that their potential exit from the niche could jeopardise the networking activity of actors in terms of interaction activity. By contrast, institutional actors do not seem to play a relevant role in clustering the ‘knowledge exchange’ network that still keeps its organisation in different sub-networks (Figure 46 D). Moreover, despite the ‘interaction’ network, financially constrained companies are distributed widely throughout the network but without occupying a central position. From this point of view, FC

should not be particularly problematic in regard to maintaining the networking activity of companies in terms of knowledge exchange.

Although not completely ready to enter the current regime, the overall findings suggest that the Italian ADB niche looks more developed in terms of knowledge, expectations, and networking compared to the other niches analysed in the thesis. Indeed, companies exhibit a medium-high level of knowledge in addition to medium expectations about the possibility for the ADB niche to fully replace the traditional fossil-based fuels. Moreover, FC seem to problematically threaten the networking activity within the niche more in terms of interactions among actors rather than in terms of knowledge exchange.

7. CONCLUSIONS

7.1 Overview of the results achieved

This thesis has investigated to what extent the existence of FC on eco-innovative companies can hinder the transition towards a green economy, by introducing a financial economics perspective within the literature on EIs and sociotechnical transitions. The thesis has combined existing knowledge from different bodies of literature, including the evolutionary analysis of sociotechnical transitions and the MLP, literature on companies' financial decisions and capital instruments, literature on the determinants of FC, the neoclassical analysis of environmental externalities and of asymmetric information in the capital markets, the VoC, literature about questionnaire design, probit models estimation, and SNA.

In particular, the thesis has developed a theoretical model aimed at analysing the way FC may jeopardise the alignment process between different sociotechnical levels that, following the MLP, are necessary for a sociotechnical transition to take place. According to the model, the presence of FC may prevent regime level companies to engage with incremental technological EIs and organisational EIs. At the same time, FC may delay the readiness of niches where radical technological EIs are developed and tested. More importantly, the thesis has provided empirical evidence to address the above two research hypotheses, by implementing (i) an econometric analysis at regime level aimed at testing the impact of FC upon the eco-innovative decisions of English and Italian manufacturing companies by means of a univariate probit model and a partial-recursive bivariate probit model, and (ii) a SNA that investigated the extent to which FC affect the readiness of niches where radical EIs are developed and tested. The niche-level investigation focused on English and Italian companies operating in two different eco-innovative niches, namely the HFC and the ADB niches. Results achieved from the empirical investigation can be summarised as follows:

1. The existence of FC may reduce the probability of manufacturing companies engaging in eco-innovative projects by up to 19% in England and 17% in Italy.

2. The existence of FC may hinder the networking activity of HFC and ADB actors, thus jeopardising the convergence process among knowledge, expectations, and networking that defines the development of an eco-innovative niche.

The above findings seem to provide evidence that the existence of FC can hinder the process of a sociotechnical transition towards a more sustainable regime. By reducing the probability for regime level companies to engage in eco-innovating projects, FC jeopardise the creation of windows of opportunity that would allow radical EIs developed at niche level to enter the dominant (unsustainable) regime. Moreover, FC interfere with the readiness of eco-innovative niches, thus hindering their possibility to enter and replace the dominant regime.

7.2 Main contributions of the thesis

The thesis has provided a number of contributions to knowledge. To assist reading, such contributions are presented in a bulleted list, in three different clustered groups, namely empirical, theoretical, and 'other' contributions.

7.2.1 Empirical contributions

The empirical contributions provided by the thesis can be assessed mainly in terms of (i) descriptive analysis of eco-innovative companies, (ii) results achieved from the econometric investigation at regime level, and (iii) findings obtained from the SNA implemented at niche level.

Descriptive analysis

Data collected allowed drawing a descriptive picture concerning companies' viewpoints upon a number of EIs-related aspects. The insights that emerged are summarised in the following highlights:

- **Technological EIs.** The text analysis has revealed that companies surveyed at regime level conceive EIs essentially as technological innovations (product and/or process innovations), thus almost entirely excluding the possibility that EIs could involve organisational, social, or institutional innovations. In other words, companies' viewpoints about what an EI is seemed to differ somewhat from the conceptualisation of EIs generally reported in the literature. This should be duly taken into account in future survey-based investigations in order to avoid the risk of technological bias when collecting data from companies.

- **Driving forces.** At regime level, most companies surveyed declared being eco-innovative mainly for competitive reasons, to save production costs, and to comply with environmental regulation. Green consumers represented another relevant external driver of EIs, particularly in the English case. Overall, descriptive statistics drew a picture detailing the eco-innovative behaviour of manufacturing companies surveyed as (i) driven by a mix of internal-to-company and external-to-company pressures, and (ii) aimed at achieving the traditional business goals of profit maximisation/cost reduction and complying with legal and regulation requirements. At niche level, the data collected depicted a picture substantially different. Although competitiveness still remains the prevailing driver of EIs in the HFC/ADB niches, the contribution provided by other driving forces (including the environmental regulation and the cost-saving needs) seems clearly weaker than at the regime level. This is probably due to the fact that, compared to niche level companies, the core business of regime level enterprises is not necessarily related to green products or services and, therefore, incremental technological EIs and organisational EIs mainly represent for them a way to accomplish environmental regulations or to reduce production costs.

- **Financial barriers.** Among companies surveyed at both regime and niche level, it is predominantly SMEs and very young enterprises that declared being financially constrained when seeking to finance their eco-innovative projects. Overall, the Italian eco-innovative companies seem to have faced more financial barriers in financing EIs than their English counterparts.

- **Environmental reputation.** The majority of companies surveyed at regime level declared that environmental reputation of enterprises can foster the possibility to gain finance and that eco-innovative companies benefit from easier access to funding. In contrast, niche level enterprises believe that environmental reputation does not contribute to financing eco-innovative projects, although they declared that operating in the HFC/ADB niches allows easier access to funding.

Econometric investigation

The thesis econometrically tested the extent to which FC can affect the probability of companies to engage in eco-innovative investments at regime level. This was achieved by determining the direct measure of existing FC that were gathered by administrating an *ad hoc* designed questionnaire to a sample of English and Italian manufacturing companies. This represents a relevant characteristic of the thesis, since most previous empirical studies that investigated the impact of FC upon the innovative decisions of companies have proxied FC by means of indirect measures (for instance the cash-flow sensitivity) that may be subject to interpretation problems. The impact of FC upon the probability of companies to eco-innovate was estimated by means of a univariate probit model. Moreover, the thesis addresses the endogeneity problem by estimating a partial-recursive bivariate probit model where the probability of having eco-innovative activities and the probability of being financially constrained are simultaneously estimated. The main results achieved from the econometric analysis are the following:

- **Eco-innovative decisions of companies negatively affected by FC.** Results achieved from the estimation of the univariate probit model suggest that the existence of FC negatively affects the eco-innovativeness of companies, by reducing the probability of the English (Italian) manufacturing enterprises surveyed to engage in eco-innovative investments by 14% (12%), *ceteris paribus*. The estimation of the partial-recursive bivariate probit broadly confirms the results above, although the estimated marginal effects are now slightly higher than before: indeed, the existence of FC now decreases the probability of an English (Italian) company starting an eco-innovative project by 19% (17%).

- **Drivers of EIs**. The econometric investigation has provided evidence about the positive impact of cost-saving needs and environmentally regulatory bodies upon the eco-innovative decisions of the English (Italian) manufacturing companies surveyed, which can increase the probability of engaging in eco-innovative activities by up to 16% (12%) and 15% (12%), respectively. Other interesting findings come from company size and age, which exert a contrasting effect upon the eco-innovative decisions of companies in the two countries. More specifically, the probability of companies to eco-innovate decreases with size in the English case, yet increases in the Italian case. Similarly, being an older company decreases (increases) the probability for English (Italian) companies to eco-innovate.

SNA

The thesis has provided empirical evidence about the impact of FC upon the readiness level of the HFC and ADB networks in England and Italy in terms of the three interlinked key mechanisms that define the development of a technological niche (i.e. expectations, learning process, and network formation). Data was collected by means of an *ad hoc* designed questionnaire aimed at building two different types of networks. The first ('interaction' network) deals with any kind of mutual interaction among niche actors, not necessarily related to HFC and ADB. The second ('knowledge exchange' network) is more relevant when it comes to assessing the impact of the network architecture in boosting

expectation convergence and learning processes, since it refers to the exchange of knowledge directly related to HFC and ADB niches. Results achieved from the SNA can be summarised as follows:

- **Impeded readiness of HFC and ADB niches due to low levels of knowledge and expectations.** Results achieved from the SNA suggest that the English and Italian HFC niches are not yet ready to enter and replace the current fossil-fuel-based regime due to the large presence of actors with a low level of knowledge and expectations. A somewhat less problematic picture emerged from the analysis of the English and Italian ADB niches. In the English case, due to the large presence of actors with a low level of knowledge about niche-related aspects, the ADB niche is still too immature to enter and replace the ongoing regime, despite the level of expectations about the future development of the niche being higher than in the HFC case. The Italian ADB niche appears clearly more developed than the English one: companies exhibit a medium level of knowledge and expectations that are, however, still insufficient to allow the niche to enter and fully replace the traditional fossil-based-fuels regime.

- **Unexploited networking potentiality of the HFC and ADB niches**. In both HFC and ADB niches, the SNA has revealed a significant decrease in all the main networking indexes (such as the number of ties, density, average degree, and inclusiveness) moving from the ‘interaction’ to the ‘knowledge exchange’ network. This suggests that only a small portion of all possible interactions among niche actors is actually used to exchange knowledge directly related to HFC/ADB production and that there exists potential for a larger number of connections that is currently unexploited. Since the emergence of a sufficiently interconnected network represents a necessary condition for an effective learning process and an upward convergence of expectations, findings suggest that the unexploited networking potential could offer great opportunities for the further development of the eco-innovative niches analysed.

- **Networking activity jeopardised by the existence of FC.** In both countries, the networking potentiality of the HFC and ADB niches seems to be jeopardised by the extensive presence of financially constrained companies within the networks. In the case of the English HFC niche, financially constrained enterprises occupy a central position in both 'interaction' and 'knowledge exchange' networks: being prevented from funding all their desired investments, such central actors can seriously hinder the interaction activity of actors as well as the channelling of knowledge flows. In the English ADB network, the widespread presence of FC affecting both central and peripheral enterprises suggests that the possible exit of some financially constrained companies from the niche should not hinder the networking activity of the remaining enterprises, neither in terms of interaction nor in terms of knowledge exchange. However, the latter is critically dependent upon the presence of institutional actors that play the important role of channelling the knowledge flow among the different sub-networks of companies. Finally, the existence of FC in both the Italian HFC and ADB niches seem to threaten the networking activity of enterprises in terms of interaction relationships more than knowledge exchange among actors.

- It is worth noting that the three qualities assessed for the HFC/ADB niche readiness (i.e. networking, expectations, and knowledge exchange) represent necessary but not sufficient requirements for a transition to take place. Indeed, a number of external-to-niche conditions (at both regime and landscape level) can jeopardise the possibility for a breakthrough to occur. In particular, a limited development and diffusion of incremental technological and organizational EIs at regime level may hinder the creation of 'windows of opportunities' that allow 'ready' niches to break out. This can be due to companies' FC (as investigated in this thesis) but also to other circumstances, such as cultural norms of behaviour and practice that can act to reinforce the regime stability. Consequently, HFC/ADB niches may remain 'hidden' even in case of convergence among networking, expectations, and knowledge exchange.

- Similarly, the lack of destabilization pressures exerted from the landscape upon the dominant regime and the HFC/ADB niches may prevent the creation of a favourable environment for the niches to break out. For instance, limited changes at landscape level may provide a too low gradient of force to drive the innovative behaviour of HFC/ADB-related companies. Similarly, exogenous shocks at landscape level, such as economic crises, may consolidate the lock-in trajectories towards a fossil-based regime due to a general decrease in aggregate demand, the associated financial crunch that affects also green investments, and austerity policies that may reduce public support of renewable energy. It is worth noting that landscape changes do not automatically shape niches and regimes but need to be perceived and translated by actors in order to exert their influence.

7.2.2 Theoretical contributions

The thesis has also provided a number of theoretical contributions to literature about EIs and sociotechnical transitions. Such contributions have been discussed in detail across chapters and therefore are summarised here only briefly.

Contribution to the literature on EIs

- **Conceptualisation of EIs**. Against the lack of a universally recognised definition of EIs in the literature, the thesis proposes a conceptualisation of the EIs that promotes a well defined classification of EIs between technological/non-technological and incremental/radical EIs, stressing the contribution that each type of EI can provide to the sociotechnical transition process towards a more sustainable regime.

- **Critical review of EIs' contribution to environmental sustainability in the framework of different theoretical approaches (evolutionary *versus* neoclassical)**. The thesis contributes to detailing the role played by EIs towards more sustainable pathways of development according to the new evolutionary studies on the techno-paradigm shifts *versus* the more

traditional neoclassical literature on innovations. Moreover, it emphasises the most relevant contribution that the two theoretical approaches can provide to the analysis of EIs. On the one side, the thesis recognises the merits of the evolutionary approach in broadening the analysis of EIs beyond the technological dimension, by taking into account the social and institutional levels and thus avoiding the risk of 'technological bias' in their analysis. On the other, it acknowledges the importance of the neoclassical view to investigate specific aspects of EIs, such as the double externality problem and the effectiveness of environmental regulation.

Contribution to the finance literature

- **Inclusion of the legal system in the evolutionary analysis of FS**. Among the determinants of FC, the thesis emphasises the role played by the FS, whose level of complexity lags behind the dichotomy between BBSs and MBSs employed so far in the literature. In particular, the thesis analyses the FS in terms of a complex institution with high interdependence parameters governing the transfer of information, the set up of incentives, and the resource allocation mechanism. Although this approach is not new to the finance literature, the thesis contributes to the evolutionary analysis of FS by broadening the set of components, which composes the FS in order to include the legal framework, i.e. the system of laws that protect shareholders and creditors in different countries.

Contribution to the literature on MLP and sociotechnical transitions

- **Assessment of the contribution of EIs to the traditional MLP model.** The thesis presents a descriptive model that is assembled from the basics of the theoretical setting of the MLP and tries to capture the contribution of EIs to the transition towards an environmentally sustainable regime where EIs become the market standard. The model describes sustainability transitions as the result of aligning the three linked levels: socio-technical landscape (i.e. the macro level), socio-technical regime (i.e. the meso level), and niche-innovations (i.e. the micro level). According to the model, forces at

landscape level (i.e. exogenous shocks and external changes) exert destabilisation pressures upon the regime and the niches, providing different gradients of force to external-to-company and internal-to-company drivers of EIs.

At regime level, such drivers push companies to develop/adopt incremental technological EIs and organisational EIs, which create windows of opportunity for niche EIs to enter the regime. EIs accumulate into stable trajectories, which occur also in social and institutional EIs and that contribute to changes on the landscape level. At niche level, drivers push companies to develop radical technological EIs. Niches provide a protected space for radical technological EIs to be tested: they struggle against the existing regime and require changes in the socio-technical regime (i.e. the development and diffusion of incremental technological EIs and organisational EIs) in order to sufficiently propagate. The readiness of a technological niche to emerge and replace the current regime can be assessed in terms of (i) convergence of expectations of niche actors about the future development of the niche, (ii) level of knowledge of niche actors about the technological and non-technological niche related aspects (e.g. infrastructure requirements, organisational issues, etc.), and (iii) number of links among niche actors, i.e. the social network architecture of the niche.

- **Inclusion of the financial dimension into the MLP**. The model presented in the thesis tries to assess the extent to which the existence of FC can hinder the transition process towards a more sustainable regime by affecting the eco-innovative behaviour of companies. More specifically, the thesis integrates the financial dimension into the original model, describing FC as a barrier that can prevent the development of EIs at regime and niche levels, thus jeopardising the alignment process between the three aforementioned levels (i.e. landscape, regime, and niche), which is necessary for a sustainability transition to occur.

7.2.3 Other contributions

- **Use of primary data.** The thesis has employed mainly primary data to address the research question, collected by means of two different *ad hoc* designed questionnaires; one addressed to regime level companies and the other to niche level enterprises. Overall, the number of valid questionnaires collected amounted to 912 (384 from English manufacturing companies, 384 from Italian manufacturing companies, 24 from English HFC companies, 24 from Italian HFC companies, 65 from English ADB companies, and 31 from Italian ADB companies). The questionnaires gathered relevant information about eco-innovative companies that, along with the possibility of implementing the econometric regressions and the SNA, allowed compiling a descriptive analysis of the eco-innovative profile of enterprises.

- **Use of a novel technique to identify eco-innovative companies.** Eco-innovative companies operating in the sociotechnical regime have been identified by exploiting the regime level questionnaire used to collect data for the econometric analysis. In other words, the questionnaire collected information about which enterprises ('who') from the sample eco-innovated and what they did ('how') to make an EI, before proceeding with gathering companies' viewpoints on a number of EI-related aspects. The distinctive characteristic of this approach is that companies surveyed were not pre-supplied with a definition of EI, but instead were asked to offer their own definition of what an EI is. Allowing respondents to provide their own opinion on what they thought EIs were, which helped to understand their viewpoint on 'who' eco-innovates and avoided forcing them to adopt a definition that they may not understand or agree with.

7.3 Limitations and further lines of research

Although the thesis provides a number of theoretical and empirical contributions, it exhibits some limitations that should be duly taken into account in future research.

Firstly, empirical evidence addressed to investigate FC at regime level is limited to a sample of 768 English and Italian manufacturing enterprises (384 companies from each country). Therefore, further evidence should be provided by employing a larger sample of manufacturing companies or extending the analysis to non-manufacturing sectors (it is worth remembering that EIs may occur in any productive sector and are not limited to 'eco-industries'). Similarly, additional empirical evidence should be provided at niche level, by investigating other eco-innovative niches along with the HFC and the ADB niches analysed in the thesis. The analysis should also be broadened to other countries in order to take into account further differences in financial architectures that may financially constrain companies. Similarly, data was collected by means of a questionnaire based upon behavioural and attitudinal measures. In particular, FC were measured by employing a direct indicator based on the company's perception about barriers faced in seeking to finance its eco-innovative activities. Future studies could employ different indicators of FC, for instance indirect measures based on internal finance (e.g. cash flow) although they are problematic in their ability to proxy FC.

Secondly, the regime-level questionnaire has gathered information about FC that were faced, not only by companies that successfully eco-innovated, but also by companies that did not eco-innovate. However, some non-eco-innovative companies answered that FC did not affect their decision to not eco-innovate. This could be because enterprises did not wish to eco-innovate (and, for this reason, they did not face FC) or because of other (non-financial) obstacles. Unfortunately, we don't know how many enterprises surveyed did not wish to eco-innovate and how many did not eco-innovate due to non-financial obstacles. Future studies could focus specifically upon 'potentially eco-innovative' companies, by dismissing enterprises from their econometric analysis that do not wish to eco-innovate.

Thirdly, the thesis has only marginally investigated the role of environmental reputation on reducing asymmetric information between eco-innovating companies and investors. As argued in section 3.3.2.5, a company's reputation

consists of a set of economic and non-economic attributes created from its past actions and can result from stakeholders' perceptions of the company's activities. Enterprises with a good environmental reputation may improve relations with external actors, such as investors and bankers, thus limiting the effects of asymmetric information. Similarly, when an environmental reputation-damaging event occurs, stakeholders may react negatively toward the company by lowering their quality of involvement, acting confrontationally toward management, demanding better contractual terms, and/or detaching from the company. In terms of the theoretical model proposed in Chapter 4, environmental reputation may be considered as a tool that could enlarge the breach within FC (dashed section of sinusoidal lines in Figure 14), thus fostering the success of EIs at both regime and niche levels. A further line of research could therefore be addressed regarding the analysis of environmental reputation and its impact upon the ability of eco-innovative companies to source finance.

Although the HFC and the ADB niches are characterised by different levels of development, a fourth limitation of the thesis is that it did not fully take into account the impact of FC upon radical EIs in the different phases of a sustainability transition. For instance, the existence of FC in the early stages of development of an eco-innovative niche could permanently prevent the transition towards a more sustainable regime. In contrast, the presence of FC in the next phases of transition (e.g. in the entry-phase of a radical EI into the regime) could delay the transition process but not necessarily prevent it. These aspects should therefore be suitably taken into account in future studies.

Finally, further investigations should be addressed regarding the analysis of green finance in order to test the extent to which they reduce the FC problems of eco-innovative companies and consequently foster the process of sociotechnical transitions towards more sustainable regimes.

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APPENDIX

A.1 The questionnaire employed for the regime-level investigation (English version)

A.2 The questionnaire employed for the regime-level investigation (Italian version)

A.3 The questionnaire employed for the HFC niche investigation (English version)

A.4 The questionnaire employed for the HFC niche investigation (Italian version)

A.5 The questionnaire employed for the ADB niche investigation (English version)

A.6 The questionnaire employed for the ADB niche investigation (Italian version)

A.1 The survey employed for the regime-level investigation (English version)

*** refers to compulsory answers**

FIRST PART (WELCOME PAGE AND QUESTIONS 1 TO 3): ALL COMPANIES

Welcome page

This is a 5 to 10 minute questionnaire.

Data collected will be employed exclusively for academic research proposals to investigate the ECO-INNOVATIVE DECISIONS of companies.

We thank you in advance for your contribution.

***Question no. 1 (Company age)**
When was your company established? (If your company is an affiliate of a multinational enterprise please refer to the national plant only).

Before 1980 ○
In 1980-1990 ○
In 1991-2000 ○
In 2001-2006 ○
In 2007-2012 ○
Don't know ○

Question no. 2 (Company's stage of development)
In which stage of development would you consider your company to be? (If your company is an affiliate of a multinational enterprise please refer to the national plant only).

SEED STAGE (assessment and development of an initial idea). ○
START-UP STAGE (development and initial marketing of the product). ○
EXPANSION STAGE (growth and expansion of the business). ○
LATER STAGE (capital replacing or exit) ○
Don't know. ○

***Question no. 3 (Company's innovative profile)**
During the six years 2007 to 2012 did your company introduce any of the following innovations:

	Yes	No
PRODUCT INNOVATIONS, i.e. the market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems. Product innovations (new or improved) must be new to your enterprise, but they do not need to be new to your market. Product innovations could have been originally developed by your enterprise or by other enterprises.	□	□
PROCESS INNOVATIONS, i.e. the implementation of a new or significantly improved production process, distribution method, or supporting activity. Process innovations must be new to your enterprise, but they do not need to be new to your market. The innovation could have been originally developed by your enterprise or by other enterprises.	□	□
ORGANISATIONAL INNOVATIONS, i.e. a new organisational method in your enterprise's business practices (including knowledge management), workplace organisation or external relations that has not been previously used by your enterprise. It must be the result of strategic decisions taken by management. Exclude mergers or acquisitions, even if for the first time.	□	□
MARKETING INNOVATIONS, i.e. the implementation of a new marketing concept or strategy that differs significantly from your enterprise's existent marketing	□	□

methods and which has not been used before. It requires significant changes in product design or packaging, product placement, product promotion or pricing. Exclude seasonal, regular and other routine changes in marketing methods.

If at least one yes → go to Question no. 4.
Otherwise → go to Question no. 18

SECOND PART (QUESTIONS 4 TO 6): INNOVATIVE COMPANIES

***Question no. 4 (Definition of eco-innovation)**
What seems to you to be an eco-innovation?

***Question no. 5 (Characteristics of eco-innovations)**
In your opinion, what are the reasons for classifying an innovation as an eco-innovation?

***Question no. 6 (Company's eco-innovativeness)**
Did your company eco-innovate in 2007-2012?
Yes ○ **→ go to Question no. 7**
No ○ **→ go to Question no. 14**

THIRD PART (QUESTIONS 7 TO 13): ECO-INNOVATIVE COMPANIES

***Question no. 7 (Description of eco-innovations introduced)**
Please describe briefly up to 3 eco-innovations your company has introduced in 2007-2012 in decreasing order of their importance:

1

2

3

Question no. 8 (Developers and adopters)
Please indicate who developed each eco-innovation described above:

	Mainly your company	Your company together with other companies or institutions	Exclusively other companies or institutions	Don't know
Eco-innovation 1	○	○	○	○
Eco-innovation 2	○	○	○	○
Eco-innovation 3	○	○	○	○

Any comment (optional):

***Question no. 9 (Drivers)**
How important were each of the following reasons in your company's decision to eco-innovate? (1 = not important ..... 4 = very important)

	1	2	3	4	Don't know
Comply with environmental regulations	○	○	○	○	○
Customers' demand	○	○	○	○	○
Pressure from environmentalists or consumer groups	○	○	○	○	○
Increase your company's competitiveness	○	○	○	○	○
Suppliers' demand	○	○	○	○	○
Pressure from industry associations	○	○	○	○	○
Reduce production costs	○	○	○	○	○

Any comment (optional):

***Question no. 10 (Sources of finance)**
Did your company use the following types of financing to eco-innovate?

	Yes	No	Don't know
Own sources / Equity	○	○	○
Share capital	○	○	○

Corporate bonds	○	○	○
Bank loans / advances	○	○	○
Private Equity (VC, BAs, etc.)	○	○	○
Public support	○	○	○

Other financing (please specify):

***Question no. 11 (Financial constraints)**

When seeking financing, how significant do you feel were the following barriers in constraining your eco-innovative activity? (1 = not significant .... 4 = very significant)

	1	2	3	4	Don't know
Potential financial suppliers insufficiently engaged with eco-innovative projects	○	○	○	○	○
Financial suppliers expected returns are different from your business goals	○	○	○	○	○
Available finance not tailored to small-scale investment needs	○	○	○	○	○
Financial supplier requested an unacceptably high level of control of your business	○	○	○	○	○
Lack of technical experience in your business as perceived by financial supplier	○	○	○	○	○
Lack of business experience in your business as perceived by financial supplier	○	○	○	○	○
Insufficient amount of collateral available	○	○	○	○	○
Limited resources dedicated to seeking or securing finance	○	○	○	○	○
Lack of knowledge of financing options	○	○	○	○	○

Any other barrier (optional):

***Question no. 12 (Environmental reputation)**

In your opinion, did your company's environmental reputation affect the access to funding eco-innovations?

Yes ○
No ○
Don't know ○

Any comment (optional):

***Question no. 13 (Easy access to funding eco-innovations)**

All in all, do you think that accessing finance is easier for eco-innovative investments than for other types of innovation?

Yes ○ **→ go to Question no. 22**
No ○ **→ go to Question no. 22**
Don't know ○ **→ go to Question no. 22**

Any comment (optional):

FOURTH PART (QUESTIONS 14 TO 17): NOT ECO-INNOVATIVE COMPANIES

***Question no. 14 (Drivers)**

Although your company did not eco-innovate, did it receive pressure to eco-innovate from:

	Yes	No	Don't know
Regulatory bodies	○	○	○
Customers	○	○	○
Environmentalists or consumer groups	○	○	○
Other companies	○	○	○
Suppliers	○	○	○
Industry associations	○	○	○
Inside the company (cost-saving needs)	○	○	○

Any comment (optional):

***Question no. 15 (Financial constraints)**
How significant do you feel were the following barriers when seeking financing in your decision to not eco-innovate? (1 = not significant .... 4 = very significant)

	1	2	3	4	Don't know
Potential financial suppliers insufficiently engaged with eco-innovative projects	○	○	○	○	○
Financial suppliers expected returns are different from your business goals	○	○	○	○	○
Available finance not tailored to small-scale investment needs	○	○	○	○	○
Financial supplier requested an unacceptably high level of control of your business	○	○	○	○	○
Lack of technical experience in your business as perceived by financial supplier	○	○	○	○	○
Lack of business experience in your business as perceived by financial supplier	○	○	○	○	○
Insufficient amount of collateral available	○	○	○	○	○
Limited resources dedicated to seeking or securing finance	○	○	○	○	○
Lack of knowledge of financing options	○	○	○	○	○

Any other barrier (optional):

***Question no. 16 (Environmental reputation)**
In your opinion, do you think that companies' environmental reputation may affect the access to funding eco-innovations?

Yes ○
No ○
Don't know ○
Any comment (optional):

***Question no. 17 (Easy access to funding eco-innovations)**
All in all, do you think that accessing finance is easier for eco-innovative investments than for other types of innovation?

Yes ○ → **go to Question no. 22**
No ○ → **go to Question no. 22**
Don't know ○ → **go to Question no. 22**
Any comment (optional):

FIFTH PART (QUESTIONS 18 TO 21): NON-INNOVATIVE COMPANIES

Question no. 18 (Definition of eco-innovation)
What seems to you to be an eco-innovation?

Question no. 19 (Characteristics of eco-innovations)
In your opinion, what are the reasons for categorising an innovation as an eco-innovation?

***Question no. 20 (Drivers)**
Although your company did not innovate, did it receive some pressure to eco-innovate from:

	Yes	No	Don't know
Regulatory bodies	○	○	○
Customers	○	○	○
Environmentalists or consumer groups	○	○	○
Other companies	○	○	○
Suppliers	○	○	○
Industry associations	○	○	○
Inside the company (cost-saving needs)	○	○	○

Any comment (optional):

***Question no. 21 (Financial constraints)**
How significant do you feel were the following barriers when seeking financing in your decision to not eco-innovate? (1 = not significant .... 4 = very significant)

	1	2	3	4	Don't know
Potential financial suppliers insufficiently engaged with eco-innovative projects	○	○	○	○	○
Financial suppliers expected returns are different from your business goals	○	○	○	○	○
Available finance not tailored to small-scale investment needs	○	○	○	○	○
Financial supplier requested an unacceptably high level of control of your business	○	○	○	○	○
Lack of technical experience in your business as perceived by financial supplier	○	○	○	○	○
Lack of business experience in your business as perceived by financial supplier	○	○	○	○	○
Insufficient amount of collateral available	○	○	○	○	○
Limited resources dedicated to seeking or securing finance	○	○	○	○	○
Lack of knowledge of financing options	○	○	○	○	○

Any other barrier (optional):

SIXT PART (QUESTION 22 AND CONCLUSIONS): ALL COMPANIES

***Question no. 22 (Identification)**
Company's name

Your first name

Your last name

Your job position in the company

Final comments

Please feel free to share any comments you may have (optional):

Thank you for your time. Your collaboration has been precious!

A.2 The survey employed for the regime-level investigation (Italian version)

*** refers to compulsory answers**

FIRST PART (WELCOME PAGE AND QUESTIONS 1 TO 3): ALL COMPANIES

Welcome page
La compilazione del questionario richiede da 5 a 10 minuti circa.

I dati raccolti saranno utilizzati esclusivamente per finalità di ricerca accademica al fine di analizzare il comportamento eco-innovativo delle imprese.

La ringraziamo in anticipo per il Suo contributo.

***Question no. 1 (Company age)**
In che anno è stata fondata la Sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)
Prima del 1980
Tra il 1980 e il 1990
Tra il 1991 e il 2000
Tra il 2001 e il 2006
Tra il 2007 e il 2012
Non so

Question no. 2 (Company's stage of development)
In quale stadio di sviluppo pensa si trovi la Sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)
FASE SEED (l'idea imprenditoriale non ancora si è concretizzata nella realizzazione di un nuovo prodotto o servizio)
FASE DI START-UP (avvio dell'attività imprenditoriale con conseguente sviluppo e commercializzazione del prodotto o servizio)
FASE DI ESPANSIONE (l'impresa ha come obiettivo primario l'accrescimento del proprio business)
FASI SUCCESSIVE (l'impresa si prepara ad uscire dal mercato o a sostituire il capitale)
NON SO

***Question no. 3 (Company's innovative profile)**
Tra il 2007 e il 2012 la Sua impresa ha introdotto:

	Sì	No
Innovazioni di PRODOTTO, cioè l'introduzione di un prodotto/servizio nuovo o migliorato, sviluppato dalla Sua o da altre imprese, nuovo per la Sua impresa ma non necessariamente per il mercato.	□	□
Innovazioni di PROCESSO, cioè l'introduzione di un processo di produzione/metodo di distribuzione nuovo o migliorato, sviluppato dalla Sua o da altre imprese, nuovo per la Sua impresa ma non necessariamente per il mercato.	□	□
Innovazioni ORGANIZZATIVE, cioè l'introduzione di un nuovo metodo organizzativo nelle pratiche commerciali della Sua impresa (escluse fusioni o acquisizioni)	□	□
Innovazioni di MARKETING, cioè la realizzazione di un nuovo metodo di marketing che attiene alla progettazione, al confezionamento o alla promozione del prodotto.	□	□

If at least one yes → go to Question no. 4.
Otherwise → go to Question no. 18

SECOND PART (QUESTIONS 4 TO 6): INNOVATIVE COMPANIES

***Question no. 4 (Definition of eco-innovation)**
Cos'è secondo Lei un'eco-innovazione?

***Question no. 5 (Characteristics of eco-innovations)**
Quali sono secondo Lei le caratteristiche in base alle quali un'innovazione può essere classificata come 'eco-innovazione'?

***Question no. 6 (Company's eco-innovativeness)**
La Sua impresa ha eco-innovato tra il 2007 e il 2012?
Sì ○ → **go to Question no. 7**
No ○ → **go to Question no. 14**

THIRD PART (QUESTIONS 7 TO 13): ECO-INNOVATIVE COMPANIES

***Question no. 7 (Description of eco-innovations introduced)**
Descriva brevemente fino a un max di 3 eco-innovazioni che la Sua impresa ha introdotto tra il 2007 e il 2012 in ordine decrescente d'importanza:
1

2

3

Question no. 8 (Developers and adopters)
Indichi chi ha sviluppato ciascuna delle eco-innovazioni da Lei descritte nella domanda precedente:

	Principalmente la Sua impresa	La Sua impresa insieme ad altre imprese / istituzioni	Esclusivamente altre imprese / istituzioni	Non so
Eco-innovazione 1	○	○	○	○
Eco-innovazione 2	○	○	○	○
Eco-innovazione 3	○	○	○	○

Eventuali commenti (opzionale):

***Question no. 9 (Drivers)**
Che importanza hanno avuto i seguenti fattori nella decisione della Sua impresa di eco-innovare? (1 = non importante ..... 4 = molto importante)

	1	2	3	4	Non so
Il rispetto delle normative ambientali	○	○	○	○	○
La domanda da parte dei Suoi clienti	○	○	○	○	○
La pressione esercitata da ambientalisti o gruppi di consumatori	○	○	○	○	○
La necessità di incrementare la competitività della Sua impresa	○	○	○	○	○
La domanda da parte dei Suoi fornitori	○	○	○	○	○
La pressione esercitata da parte di organizzazioni di categoria	○	○	○	○	○
La riduzione dei costi di produzione	○	○	○	○	○

Eventuali commenti (opzionale):

***Question no. 10 (Sources of finance)**
A quali tipi di finanziamento ha fatto ricorso la Sua impresa per eco-innovare?

	Sì	No	Non so
Fonti proprie	○	○	○
Capitale azionario	○	○	○
Obbligazioni	○	○	○
Prestiti bancari	○	○	○
Private equity (Venture capital, Business angel, ecc.)	○	○	○
Finanziamenti pubblici	○	○	○

Altre forme di finanziamento (specificare) (opzionale):

***Question no. 11 (Financial constraints)**
Nel reperire finanziamenti, quanto sono stati significativi i seguenti fattori nel limitare l'attività eco-innovativa della Sua impresa? (1 = non significativo .... 4 = molto significativo)

	1	2	3	4	Non

					so
Potenziali investitori non sufficientemente esperti nel campo delle eco-innovazioni	○	○	○	○	○
Obiettivi dei potenziali investitori differenti da quelli della Sua impresa	○	○	○	○	○
Tipologie di finanziamento non adatte ai piccoli investimenti in eco-innovazioni	○	○	○	○	○
Ulteriori ostacoli esterni (opzionale)					
Eccessiva ingerenza nella gestione della Sua impresa da parte dei potenziali investitori	○	○	○	○	○
Mancanza di esperienza tecnica percepita dai potenziali investitori	○	○	○	○	○
Mancanza di esperienza imprenditoriale percepita dai potenziali investitori	○	○	○	○	○
Insufficienti garanzie disponibili	○	○	○	○	○
Limitatezza delle risorse dedicate alla ricerca dei finanziamenti	○	○	○	○	○
Scarsa conoscenza delle possibili opzioni di finanziamento	○	○	○	○	○
Ulteriori ostacoli (opzionale)					

***Question no. 12 (Environmental reputation)**
Ritiene che la reputazione ambientale della Sua impresa abbia influito sulla capacità di ottenere finanziamenti per eco-innovare?

Sì ○
No ○
Non so ○
Eventuali commenti (opzionale):

***Question no. 13 (Easy access to funding eco-innovations)**
Ritiene sia più facile reperire finanziamenti per investimenti eco-innovativi piuttosto che per altri tipi di innovazioni?

Sì ○ **→ go to Question no. 22**
No ○ **→ go to Question no. 22**
Non so ○ **→ go to Question no. 22**

FOURTH PART (QUESTIONS 14 TO 17): NOT ECO-INNOVATIVE COMPANIES

***Question no. 14 (Drivers)**
Sebbene non abbia eco-innovato, la Sua impresa ha comunque ricevuto pressioni affinché eco-innovasse da parte di:

	Sì	No	Non so
Organismi di regolamentazione ambientale	○	○	○
Clienti	○	○	○
Gruppi di ambientalisti o di consumatori	○	○	○
Altre imprese	○	○	○
Fornitori	○	○	○
Associazioni di categoria	○	○	○
Driver interni all'impresa (ad.es. esigenze di riduzione dei costi di produzione)	○	○	○

Eventuali commenti (opzionale):

***Question no. 15 (Financial constraints)**
Nel reperire finanziamenti, quanto sono stati significativi i seguenti fattori nel limitare l'attività eco-innovativa della Sua impresa? (1 = non significativo .... 4 = molto significativo)

	1	2	3	4	Non so
Potenziali investitori non sufficientemente esperti nel campo delle eco-innovazioni	○	○	○	○	○
Obiettivi dei potenziali investitori differenti da quelli della Sua impresa	○	○	○	○	○
Tipologie di finanziamento non adatte ai piccoli investimenti in eco-innovazioni	○	○	○	○	○
Ulteriori ostacoli esterni (opzionale)					
Eccessiva ingerenza nella gestione della Sua impresa da parte dei potenziali investitori	○	○	○	○	○
Mancanza di esperienza tecnica percepita dai	○	○	○	○	○

potenziali investitori					
Mancanza di esperienza imprenditoriale percepita dai potenziali investitori	○	○	○	○	○
Insufficienti garanzie disponibili	○	○	○	○	○
Limitatezza delle risorse dedicate alla ricerca dei finanziamenti	○	○	○	○	○
Scarsa conoscenza delle possibili opzioni di finanziamento	○	○	○	○	○
Ulteriori ostacoli (opzionale)					

***Question no. 16 (Environmental reputation)**
Ritiene che la reputazione ambientale di un'impresa possa influenzare la sua capacità di reperire finanziamenti per investimenti eco-innovativi?

Sì ○
No ○
No so ○
Eventuali commenti (opzionale)

***Question no. 17 (Easy access to funding eco-innovations)**
Ritiene sia più facile reperire finanziamenti per investimenti eco-innovativi piuttosto che per altri tipi di innovazioni?

Sì ○ **→ go to Question no. 22**
No ○ **→ go to Question no. 22**
Non so ○ **→ go to Question no. 22**
Eventuali commenti (opzionale):

FIFTH PART (QUESTIONS 18 TO 21): NOT INNOVATIVE COMPANIES

Question no. 18 (Definition of eco-innovation)
Cos'è secondo Lei un'eco-innovazione?

Question no. 19 (Characteristics of eco-innovations)
Quali sono secondo Lei le caratteristiche in base alle quali un'innovazione può essere classificata come 'eco-innovazione'?

***Question no. 20 (Drivers)**
Sebbene non abbia innovato, la Sua impresa ha comunque ricevuto pressioni affinché eco-innovasse da parte di:

	Sì	No	Non so
Organismi di regolamentazione ambientale	○	○	○
Clienti	○	○	○
Gruppi di ambientalisti o di consumatori	○	○	○
Altre imprese	○	○	○
Fornitori	○	○	○
Associazioni di categoria	○	○	○
Driver interni all'impresa (ad.es. esigenze di riduzione dei costi di produzione)	○	○	○

Eventuali commenti (opzionale):

***Question no. 21 (Financial constraints)**
Nel reperire finanziamenti, quanto sono stati significativi i seguenti fattori nel limitare l'attività eco-innovativa della Sua impresa? (1 = non significativo .... 4 = molto significativo)

	1	2	3	4	Non so
Potenziali investitori non sufficientemente esperti nel campo delle eco-innovazioni	○	○	○	○	○
Obiettivi dei potenziali investitori differenti da quelli della Sua impresa	○	○	○	○	○
Tipologie di finanziamento non adatte ai piccoli investimenti in eco-innovazioni	○	○	○	○	○
Ulteriori ostacoli esterni (opzionale)					
Eccessiva ingerenza nella gestione della Sua impresa da parte dei potenziali investitori	○	○	○	○	○
Mancanza di esperienza tecnica percepita dai potenziali investitori	○	○	○	○	○
Mancanza di esperienza imprenditoriale percepita dai potenziali investitori	○	○	○	○	○
Insufficienti garanzie disponibili	○	○	○	○	○

Limitatezza delle risorse dedicate alla ricerca dei finanziamenti	○	○	○	○	○
Scarsa conoscenza delle possibili opzioni di finanziamento	○	○	○	○	○

Ulteriori ostacoli (opzionale)

SIXT PART (QUESTION 22 AND CONCLUSIONS): ALL COMPANIES

***Question no. 22 (Identification)**
Nome dell'impresa

Il Suo nome

Il Suo cognome

La Sua posizione lavorativa (il Suo ruolo) all'interno dell'impresa

Final comments
Eventuali osservazioni o commenti (opzionale):

La ringrazio per il tempo che ha dedicato alla compilazione del questionario.

La Sua collaborazione è stata preziosa!

A.3 The survey employed for investigating the HFC niche (English version)

*** refers to compulsory answers**

FIRST PART (WELCOME PAGE AND QUESTIONS 1 TO 8

Welcome page

This is a 10 to 15 minute questionnaire.

The data collected will be employed exclusively for academic research proposals to investigate the ECO-INNOVATIVE DECISIONS of companies.

We thank you in advance for your contribution.

***Question no. 1 (Company size)**
How many employees does your company have? (If your company is an affiliate of a multinational enterprises please refer to the national plant only).

Less than 10	○
10-49	○
50-249	○
250 or more	○
Don't know	○

***Question no. 2 (Company age)**
When was your company established? (If your company is an affiliate of a multinational enterprise please refer to the national plant only).

Before 1980	○
In 1980-1990	○
In 1991-2000	○
In 2001-2006	○

In 2007-2012	○
After 2012	○
Don’t know	○

Question no. 3 (Company stage of development)
In which stage of development would you consider your company to be? (If your company is an affiliate of a multinational enterprise please refer to the national plant only).

SEED STAGE (assessment and development of an initial idea)	○
START-UP STAGE (development and initial marketing of the product)	○
EXPANSION STAGE (growth and expansion of the business)	○
LATER STAGE (capital replacing or exit)	○
Don’t know	○

***Question no. 4 (Drivers)**
How important were each of the following reasons in your company’s decision to operate in the Hydrogen and Fuel Cells (HFC) sector? (1 = not important ..... 4 = very important)

	1	2	3	4	Don't know
Comply with environmental regulations	○	○	○	○	○
Customers’ demand	○	○	○	○	○
Pressure from environmentalists or consumer groups	○	○	○	○	○
Increase your company's competitiveness	○	○	○	○	○
Suppliers’ demand	○	○	○	○	○
Pressure from industry associations	○	○	○	○	○
Reduce production costs	○	○	○	○	○

Any comment (optional):

***Question no. 5 (Sources of finance)**
Did your company use the following types of financing?

	Yes	No	Don't know
Own sources / Equity	○	○	○
Share capital	○	○	○
Corporate bonds	○	○	○
Bank loans / advances	○	○	○
Private Equity (VC, BAs, etc.)	○	○	○
Public support	○	○	○

Other financing (please specify):

***Question no. 6 (Financial constraints)**
When seeking financing, how significant do you feel were the following barriers in constraining your innovation activity? (1 = not significant .... 4 = very significant)

	1	2	3	4	Don't know
Potential financial suppliers insufficiently engaged with eco-innovative projects	○	○	○	○	○
Financial suppliers expected returns are different from your business goals	○	○	○	○	○
Available finance not tailored to small-scale investment needs	○	○	○	○	○
Financial supplier requested an unacceptably high level of control of your business	○	○	○	○	○
Lack of technical experience in your business as perceived by financial supplier	○	○	○	○	○
Lack of business experience in your business as perceived by financial supplier	○	○	○	○	○
Insufficient amount of collateral	○	○	○	○	○

available					
Limited resources dedicated to seeking or securing finance	○	○	○	○	○
Lack of knowledge of financing options	○	○	○	○	○

Any other barrier (optional):

***Question no. 7 (Environmental reputation)**
In your opinion, did your company's environmental reputation affect access to funding?

Yes ○
No ○
Don't know ○
Any comment (optional):

***Question no. 8 (Easy access to funding eco-innovations)**
All in all, do you think that accessing finance is easier for eco-innovative investments than for other types of innovation?

Yes ○
No ○
Don't know ○
Any comment (optional):

SECOND PART (QUESTIONS 9 AND 10)

***Question no. 9 (Expectations)**
In your opinion, how long will it take for the full transition towards the use of HFC only?

Less than 10 years ○
Between 10 and 20 years ○
More than 20 years ○
HFC will never permanently replace fossil fuels ○

***Question no. 10 (Knowledge)**
In the last three years, how many meetings, round-tables, conferences etc. about HFC did you organise or take part in?

None ○
1-2 ○
3-4 ○
5 or more ○

THIRD PART (QUESTIONS 11 TO 13)

In order to explore the impact of financial constraints on the HFC industry we aim to use a 'Social Network Analysis' (SNA) approach. SNA allows designing networks of interactions between HFC actors and investigates the way they are affected by financial constraints. We report below a list including the main HFC actors, asking you what kind of relationship ('Generic Interaction', 'Knowledge Exchange', or 'None'), did you have with them.
Please note that:

- 'Generic interaction' refers to any kind of mutual interface among actors, not specifically restrained to HFC related interactions.
- 'Knowledge exchange' refers specifically to the exchange of knowledge among actors restrained to HFC.

***Question no. 11 (Network design - Producers)**
In the last three years, what kind of relationship did you have with the following HFC PRODUCERS? (Please disregard the option with your company's name)

	Only Generic Interaction	Generic Interaction and Knowledge Exchange	None
1. Air liquide	○	○	○
2. Auriga Energy	○	○	○
3. Air products	○	○	○
4. Alstom	○	○	○
5. BOC	○	○	○
6. Acal Energy	○	○	○

7. Johnson and Matthey	○	○	○
8. Intelligent energy	○	○	○
9. ITM Power	○	○	○
10. Rolls Royce	○	○	○
11. Fuel cell systems	○	○	○
12. Cella energy	○	○	○
13. Amec foster wheeler	○	○	○
14. AFC energy	○	○	○
15. Bronkhorst UK	○	○	○
16. Ceres Power	○	○	○
17. Amalyst	○	○	○
18. Fuel cell energy solutions	○	○	○
19. Adelan	○	○	○
20. Ceramic fuel cells	○	○	○
21. Chesterfield special cylinders	○	○	○

***Question no. 12 (Network design – Distributors/Service providers)**
In the last three years, what kind of relationship did you have with the following HFC DISTRIBUTORS/SERVICE PROVIDERS? (Please disregard the option with your company's name)

	Only Generic Interaction	Generic Interaction and Knowledge Exchange	None
22. Eon	○	○	○
23. SSE	○	○	○
24. Cenex	○	○	○
25. KIWA (Gastec at CRE)	○	○	○
26. MMI	○	○	○
27. Waste2Tricity	○	○	○
28. Arcola energy	○	○	○
29. Ulemco	○	○	○
30. CCS Global	○	○	○
31. Element Energy	○	○	○
32. Swindon Commercial Services	○	○	○
33. Briggs Equipment	○	○	○
34. Commercial Group	○	○	○
35. Revolve Technologies	○	○	○

***Question no. 13 (Network design – Institutional actors/project partners)**
In the last three years, what kind of relationship did you have with the following HFC INSTITUTIONAL ACTORS/PROJECTS PARTNERS?

	Only Generic Interaction	Generic Interaction and Knowledge Exchange	None
36. UK HFCA	○	○	○
37. University of Birmingham fuel cells group	○	○	○
38. Newcastle University	○	○	○
39. Science and technology facilities council	○	○	○
40. The university of Nottingham	○	○	○
41. Manchester Metropolitan University	○	○	○
42. WMG innovative solutions (Warwick University)	○	○	○
43. High Value Manufacturing Catapult	○	○	○
44. Hydrogen London	○	○	○
45. Department for Business Innovation & Skills	○	○	○
46. Department of Energy & Climate Change	○	○	○
47. Department for Transport	○	○	○
48 Greater London Authority	○	○	○
49. Europ. Fuel Cells & Hydrogen Joint Undertak.	○	○	○
50. Innovate UK	○	○	○
51. Bristol City Council	○	○	○
52. Bristol Packet Boats	○	○	○
53. FirstGroup	○	○	○
54. Stagecoach	○	○	○
55. Daimler	○	○	○

56. Honda	○	○	○
57. Hyundai	○	○	○
58. Nissan	○	○	○
59. Toyota	○	○	○
60. Morrisons	○	○	○
61. Sainsbury	○	○	○
62. Heathrow Airport	○	○	○

FOURTH PART (QUESTION 14 AND CONCLUSIONS)

***Question no. 14 (Identification)**
Company's name

Your first name

Your last name

Your job position in the company

Final comments

Please feel free to share any comments you may have (optional):

Thank you for your time. Your collaboration has been precious!

A.4 The survey employed for investigating the HFC niche (Italian version)

*** refers to compulsory answers**

FIRST PART (WELCOME PAGE AND QUESTIONS 1 TO 8)

Welcome page

La compilazione del questionario richiede da 10 a 15 minuti circa.

I dati raccolti saranno utilizzati esclusivamente per finalità di ricerca accademica al fine di analizzare il comportamento eco-innovativo delle imprese.

La ringraziamo in anticipo per il Suo contributo.

***Question no. 1 (Company size)**
Quanti dipendenti ha la sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)

Meno di 10	○
Tra 10 e 49	○
Tra 50 e 249	○
250 o più	○
Non so	○

***Question no. 2 (Company age)**
In che anno è stata fondata la Sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)

Prima del 1980	○
Tra il 1980 e il 1990	○
Tra il 1991 e il 2000	○
Tra il 2001 e il 2006	○
Tra il 2007 e il 2012	○

Dopo il 2012	○
Non so	○

***Question no. 3 (Company's stage of development)**
In quale stadio di sviluppo pensa si trovi la Sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)
FASE SEED (l'idea imprenditoriale non ancora si è concretizzata nella realizzazione di un nuovo prodotto o servizio)
FASE DI START-UP (avvio dell'attività imprenditoriale con conseguente sviluppo e commercializzazione del prodotto o servizio)
FASE DI ESPANSIONE (l'impresa ha come obiettivo primario l'accrescimento del proprio business)
FASI SUCCESSIVE (l'impresa si prepara ad uscire dal mercato o a sostituire il capitale)
NON SO

***Question no. 4 (Drivers)**
Che importanza hanno avuto i seguenti fattori nella decisione della Sua impresa di operare nel settore dell'idrogeno e delle celle a combustibile ? (1 = non importante ..... 4 = molto importante)

	1	2	3	4	Non so
Il rispetto delle normative ambientali	○	○	○	○	○
La domanda da parte dei Suoi clienti	○	○	○	○	○
La pressione esercitata da ambientalisti o gruppi di consumatori	○	○	○	○	○
La necessità di incrementare la competitività della Sua impresa	○	○	○	○	○
La domanda da parte dei Suoi fornitori	○	○	○	○	○
La pressione esercitata da parte di organizzazioni di categoria	○	○	○	○	○
La riduzione dei costi di produzione	○	○	○	○	○

Eventuali commenti (opzionale):

***Question no. 5 (Sources of finance)**
A quali tipi di finanziamento ha fatto ricorso la Sua impresa?

	Sì	No	Non so
Fonti proprie	○	○	○
Capitale azionario	○	○	○
Obbligazioni	○	○	○
Prestiti bancari	○	○	○
Private equity (Venture capital, Business angel, ecc.)	○	○	○
Finanziamenti pubblici	○	○	○

Altre forme di finanziamento (specificare) (opzionale):

***Question no. 6 (Financial constraints)**
Nel reperire finanziamenti, quanto sono stati significativi i seguenti fattori nel limitare l'attività innovativa della Sua impresa? (1 = non significativo .... 4 = molto significativo)

	1	2	3	4	Non so
Potenziali investitori non sufficientemente esperti nel campo delle eco-innovazioni	○	○	○	○	○
Obiettivi dei potenziali investitori differenti da quelli della Sua impresa	○	○	○	○	○
Tipologie di finanziamento non adatte ai piccoli investimenti in eco-innovazioni	○	○	○	○	○
Ulteriori ostacoli esterni (opzionale)					
Eccessiva ingerenza nella gestione della Sua impresa da parte dei potenziali investitori	○	○	○	○	○
Mancanza di esperienza tecnica percepita dai potenziali investitori	○	○	○	○	○
Mancanza di esperienza imprenditoriale percepita dai potenziali investitori	○	○	○	○	○
Insufficienti garanzie disponibili	○	○	○	○	○
Limitatezza delle risorse dedicate alla ricerca dei finanziamenti	○	○	○	○	○

Scarsa conoscenza delle possibili opzioni di finanziamento	○	○	○	○	○
Ulteriori ostacoli (opzionale)					

***Question no. 7 (Environmental reputation)**
Ritiene che la reputazione ambientale della Sua impresa abbia influito sulla capacità di ottenere finanziamenti?

Sì ○
No ○
Non so ○
Eventuali commenti (opzionale):

***Question no. 8 (Easy access to funding eco-innovations)**
Ritiene sia più facile reperire finanziamenti per investimenti eco-innovativi piuttosto che per altri tipi di innovazioni?

Sì ○
No ○
Non so ○

SECOND PART (QUESTIONS 9 AND 10)

***Question no. 9 (Expectations)**
Quanto tempo ritiene sia ancora necessario perché si completi il passaggio all'utilizzo di solo idrogeno e celle a combustibile?

Meno di 10 anni ○
Tra 10 e 20 anni ○
Più di 20 anni ○
Non penso che l'idrogeno e le celle a combustibile riusciranno a sostituire definitivamente i carburanti tradizionali ○

***Question no. 10 (Knowledge)**
A quanti convegni, conferenze, tavole rotonde, ecc. con a tema l'idrogeno e le celle a combustibile ha preso parte (o ha organizzato) negli ultimi tre anni?

Nessuno ○
1-2 ○
3-4 ○
5 or more ○

THIRD PART (QUESTIONS 11 TO 13)

Per analizzare l'impatto dei vincoli finanziari nel settore dell'idrogeno e delle celle a combustibile, utilizzeremo una metodologia di ricerca definita 'Social Network Analysis' (SNA). La SNA consiste nel disegnare le reti di interazione tra gli attori operanti nel settore dell'idrogeno e delle celle a combustibile per poi verificare come tali reti sino eventualmente influenzate dall'esistenza di vincoli finanziari. Le elencheremo pertanto i nomi dei principali attori operanti nel settore dell'idrogeno e delle celle a combustibile chiedendoLe che tipo di interazione la Sua impresa ha avuto con loro negli ultimi tre anni ('Interazione Generica', 'Scambio di Conoscenze', 'Nessuna Interazione').
Si noti che:

- 'Interazione Generica' si rifersice a qualsiasi tipo di eventuali interazioni intercorse tra gli attori, non necessariamente legate alla produzione/utilizzo dell'idrogeno e delle celle a combustibile.
- 'Scambio di Conoscenze' si riferisce, invece, ad un eventuale scambio di conoscenze relativo alla produzione/utilizzo dell'idrogeno e delle celle a combustibile.

***Question no. 11 (Network design - Producers)**
Che tipo di relazione ha avuto negli ultimi tre anni con i seguenti PRODUTTORI di idrogeno e celle a combustibile? (non tenga conto del rigo con il nome della Sua impresa)

	Solo Interazione Generica	Interazione Generica e Scambio di Conoscenze	Nessuna Interazione
1. Sol	○	○	○
2. Air Liquide	○	○	○
3. Linde Gas	○	○	○
4. Sapio	○	○	○
5. Ansaldo Fuel Cells	○	○	○

6. Acta	○	○	○
7. Aea	○	○	○
8. Bitron	○	○	○
9. Dalmine	○	○	○
10. Ducati Energia	○	○	○
11. E.D.I. Progetti e Sviluppo	○	○	○
12. Enginsoft	○	○	○
13. Electro Power Systems	○	○	○
Type size issue – better to wrap with longer ones than reduce type size…	○	○	○
14. El.Ma. Electronic Machining			
15. Faber Industrie	○	○	○
16. Fiamm Energy Storage Solut.	○	○	○
17. Genport	○	○	○
18. H2nitidor	○	○	○
19. Hysytech	○	○	○
20. Matres	○	○	○
21. Mbn Nanomaterialia	○	○	○
22. Onda	○	○	○
23. Sensitron	○	○	○
24. Solid Power	○	○	○
25. Solvay Specialty Polymers	○	○	○
26. Turbo Service Torino	○	○	○
27. Turbocoating	○	○	○
28. Siel	○	○	○

***Question no. 12 (Network design – Distributors/Service providers)**
Che tipo di relazione ha avuto negli ultimi tre anni con i seguenti DISTRIBUTORI/FORNITORI DI SERVIZI di idrogeno e celle a combustibile? (non tenga conto del rigo con il nome della Sua impresa)

	Solo Interazione Generica	Interazione Generica e Scambio di Conoscenze	Nessuna Interazione
29. Dolomiti Energia	○	○	○
30. Edison	○	○	○
31. Tre - Tozzi Renewable Energy	○	○	○
32. Fit Consulting	○	○	○
33. CESI Ricerca	○	○	○

***Question no. 13 (Network design – Institutional actors/project partners)**
Che tipo di relazione ha avuto negli ultimi tre anni con i seguenti ATTORI ISTITUZIONALI/PARTNERS DI PROGETTI?

	Solo Interazione Generica	Interazione Generica e Scambio di Conoscenze	Nessuna Interazione
34. H2IT	○	○	○
35. Ministero dell'Ambiente	○	○	○
36. Ministero dello Sviluppo Economico	○	○	○
37. Confindustria	○	○	○
38. Politecnico di Milano	○	○	○
39. Politecnico di Torino	○	○	○
40. Univ. Campus Bio di Roma	○	○	○
41. Univ. di Genova	○	○	○
42. Univ. di Napoli Parthenope	○	○	○
43. Univ. di Padova	○	○	○
44. Univ. di Perugia	○	○	○
45. Univ. di Roma La Sapienza	○	○	○
46. Univ. di Roma Tor Vergata	○	○	○
47. Univ. di Salerno	○	○	○
48. Univ. di Torino	○	○	○
49. Univ. di Pisa	○	○	○
50. Ag. Naz. per le Nuove Tecn., l'Energia e lo Svil. Econ. Sost.	○	○	○
51. Centro Ricerche Fiat	○	○	○
52. Regione Lazio	○	○	○
53. Regione Liguria	○	○	○

54. Parco Scient. e Tecn. per l'ambiente	○	○	○
55. Centro Sviluppo Materiali	○	○	○
56. CNR	○	○	○
57. Fast – Feder. delle Associaz. Scient. e Tecniche	○	○	○
58. Istituto Per Innovazioni Tecnologiche Bolzano	○	○	○
59. ENEA	○	○	○

FOURTH PART (QUESTION 14 AND CONCLUSIONS)

***Question no. 14 (Identification)**
Nome dell'impresa

Il Suo nome

Il Suo cognome

La Sua posizione lavorativa (il Suo ruolo) all'interno dell'impresa

Final comments
Eventuali osservazioni o commenti (opzionale):

La ringrazio per il tempo che ha dedicato alla compilazione del questionario.

La Sua collaborazione è stata preziosa!

A.5 The survey employed for investigating the ADB niche (English version)

*** refers to compulsory answers**

FIRST PART (WELCOME PAGE AND QUESTIONS 1 TO 8)

Welcome page

This is a 10 to 15 minute questionnaire.

The data collected will be employed exclusively for academic research proposals to investigate the ECO-INNOVATIVE DECISIONS of companies.

We thank you in advance for your contribution.

***Question no. 1 (Company size)**
How many employees does your company have? (If your company is an affiliate of a multinational enterprises please refer to the national plant only).

Less than 10	○
10-49	○
50-249	○
250 or more	○
Don't know	○

***Question no. 2 (Company age)**
When was your company established? (If your company is an affiliate of a multinational enterprise please refer to the national plant only).

Before 1980	○
In 1980-1990	○
In 1991-2000	○
In 2001-2006	○

In 2007-2012	○
After 2012	○
Don't know	○

Question no. 3 (Company stage of development)
In which stage of development would you consider your company to be? (If your company is an affiliate of a multinational enterprise please refer to the national plant only).

SEED STAGE (assessment and development of an initial idea)	○
START-UP STAGE (development and initial marketing of the product)	○
EXPANSION STAGE (growth and expansion of the business)	○
LATER STAGE (capital replacing or exit)	○
Don’t know	○

***Question no. 4 (Drivers)**
How important were each of the following reasons in your company’s decision to operate in the Anaerobic Digestion and Biogas (ADB) sector? (1 = not important ..... 4 = very important)

	1	2	3	4	Don't know
Comply with environmental regulations	○	○	○	○	○
Customers’ demand	○	○	○	○	○
Pressure from environmentalists or consumer groups	○	○	○	○	○
Increase your company's competitiveness	○	○	○	○	○
Suppliers’ demand	○	○	○	○	○
Pressure from industry associations	○	○	○	○	○
Reduce production costs	○	○	○	○	○

Any comment (optional):

***Question no. 5 (Sources of finance)**
Did your company use the following types of financing?

	Yes	No	Don't know
Own sources / Equity	○	○	○
Share capital	○	○	○
Corporate bonds	○	○	○
Bank loans / advances	○	○	○
Private Equity (VC, BAs, etc.)	○	○	○
Public support	○	○	○

Other financing (please specify):

***Question no. 6 (Financial constraints)**
When seeking financing, how significant do you feel were the following barriers in constraining your innovation activity? (1 = not significant .... 4 = very significant)

	1	2	3	4	Don't know
Potential financial suppliers insufficiently engaged with eco-innovative projects	○	○	○	○	○
Financial suppliers expected returns are different from your business goals	○	○	○	○	○
Available finance not tailored to small-scale investment needs	○	○	○	○	○
Financial supplier requested an unacceptably high level of control of your business	○	○	○	○	○
Lack of technical experience in your business as perceived by financial supplier	○	○	○	○	○
Lack of business experience in your business as perceived by financial supplier	○	○	○	○	○
Insufficient amount of collateral	○	○	○	○	○

available					
Limited resources dedicated to seeking or securing finance	○	○	○	○	○
Lack of knowledge of financing options	○	○	○	○	○

Any other barrier (optional):

***Question no. 7 (Environmental reputation)**

In your opinion, did your company's environmental reputation affect access to funding?

Yes ○
No ○
Don't know ○

Any comment (optional):

***Question no. 8 (Easy access to funding eco-innovations)**

All in all, do you think that accessing finance is easier for eco-innovative investments than for other types of innovation?

Yes ○
No ○
Don't know ○

Any comment (optional):

SECOND PART (QUESTIONS 9 AND 10)

***Question no. 9 (Expectations)**

In your opinion, how long will it take for the full transition towards the use of biogas only?

Less than 10 years ○
Between 10 and 20 years ○
More than 20 years ○
ADB will never permanently replace fossil fuels ○

***Question no. 10 (Knowledge)**

In the last three years, how many meetings, round-tables, conferences etc. about ADB did you organise or take part in?

None ○
1-2 ○
3-4 ○
5 or more ○

THIRD PART (QUESTIONS 11 AND 12)

In order to explore the impact of financial constraints on the HFC In order to explore the impact of financial constraints in the ADB industry we aim to use a 'Social Network Analysis' (SNA) approach. SNA allows designing networks of interactions between ADB actors and investigates the way they are affected by financial constraints. We report below a list including the main ADB actors, asking you what kind of relationship ('Generic Interaction', 'Knowledge Exchange', or 'None'), did you have with them.

Please note that:

- 'Generic interaction' refers to any kind of mutual interface among actors, not specifically restrained to ADB related interactions.
- 'Knowledge exchange' refers specifically to the exchange of knowledge among actors restrained to ADB.

***Question no. 11 (Network design – Operators & Plant Suppliers)**

In the last three years, what kind of relationship did you have with the following ADB OPERATORS & PLANT SUPPLIERS? (Please disregard the option with your company's name)

	Only Generic Interaction	Generic Interaction Knowledge Exchange	None
1. 2G Energy	○	○	○
2. A-Consult	○	○	○
3. Acrefield Developments	○	○	○
4. Activated Carbon Systems	○	○	○
5. Aerocover	○	○	○

6. AeroThermal Group	○	○	○
7. Agrico Engineering Sales	○	○	○
8. Agrikomp UK	○	○	○
9. Air Management & Design	○	○	○
10. Allison Engineering	○	○	○
11. Allvalves	○	○	○
12. Alvan Blanch	○	○	○
13. Ameram	○	○	○
14. Anua	○	○	○
15. Atritor	○	○	○
16. AFS	○	○	○
17. Balmoral Tanks	○	○	○
18. Binowa GmbH	○	○	○
19. Biogas Optimisation	○	○	○
20. Biomethane	○	○	○
21. BOCK UK	○	○	○
22. Börger	○	○	○
23. Bosta UK	○	○	○
24. CBS Concrete Products	○	○	○
25. Clarke Energy	○	○	○
26. CooperÖstlund	○	○	○
27. CSO Technik	○	○	○
28. CZERO	○	○	○
29. Edina	○	○	○
30. Eggersmann Anlagenbau	○	○	○
31. Elmac Technologies	○	○	○
32. Enviroseal Lining Solutions	○	○	○
33. ETP Services	○	○	○
34. Evergreen Gas	○	○	○
35. Finning UK	○	○	○
36. FLI Energy	○	○	○
37. Flow Components	○	○	○
38. Gen-C	○	○	○
39. Green and Pleasant Renewables	○	○	○
40. Greencrop	○	○	○
41. Haarslev UK	○	○	○
42. Hayes GFS	○	○	○
43. Heat and Power Services	○	○	○
44. HRS Heat Exchangers	○	○	○
45. Huber Technology	○	○	○
46. Hydro International	○	○	○
47. Hydrothane STP	○	○	○
48. Infineum Group	○	○	○
49. Juta UK	○	○	○
50. Kings Industrial Boilers	○	○	○
51. Kirk Environmental	○	○	○
52. Landfill Systems	○	○	○
53. Landia UK	○	○	○
54. Leengate valves	○	○	○
55. Libertine FPE	○	○	○
56. LTS Systems	○	○	○
57. Major Equipment	○	○	○
58. Metamo Process Technology	○	○	○
59. Monsal	○	○	○
60. Mosscliff Environmental	○	○	○
61. MSE Hiller	○	○	○
62. NETZSCH Pumps	○	○	○
63. New Generation Biogas (NGB)	○	○	○
64. Nijhuis-H2OK	○	○	○
65. Northey Technologies	○	○	○
66. Omex	○	○	○
67. PlanET Biogas UK	○	○	○
68. Protego UK	○	○	○
69. Purac Puregas	○	○	○

70. Reliant Installations	○	○	○
71. Richard Larrington Trailers	○	○	○
72. Stream BioEnergy	○	○	○
73. System Mix	○	○	○
74. ThermTech	○	○	○
75. TRAMSPREAD	○	○	○
76. T-T Pumps	○	○	○
77. Uniflare	○	○	○
78. UTS Biogas	○	○	○
79. Vogelsang	○	○	○
80. Wehrle Environmental	○	○	○
81. WELTEC BIOPOWER UK	○	○	○
82. Xergi	○	○	○

***Question no. 12 (Network design – Institutional Actors, Utilities, Universities)**
In the last three years, what kind of relationship did you have with the following ADB INSTITUTIONAL ACTORS, UTILITIES, UNIVERSITIES?

	Only Generic Interaction	Generic Interaction Knowledge Exchange	None
83. ADBA			
84. Environmental Agency (EA)	○	○	○
85. Harper Adams Energy	○	○	○
86. Lincolnshire County Council	○	○	○
87. Centre for Process Innovation	○	○	○
88. Cranfield University	○	○	○
89. Lancaster Environment Centre	○	○	○
90. University of Leicester	○	○	○
91. University of Southampton	○	○	○
92. Calor Gas	○	○	○
93. Ecotricity group	○	○	○
94. Flogas Britain	○	○	○
95. GENeco	○	○	○
96. National Grid	○	○	○
97. Severn Trent Water	○	○	○
98. SGN Commercial Services	○	○	○
99. Thames Water Utilities	○	○	○
100. Total Gas &Power	○	○	○
101. Warrington	○	○	○

FOURTH PART (QUESTION 13 AND CONCLUSIONS)

***Question no. 13 (Identification)**
Company's name

Your first name

Your last name

Your job position in the company

Final comments

Please feel free to share any comments you may have (optional):

Thank you for your time. Your collaboration has been precious!

A.6 The survey employed for investigating the ADB niche (Italian version)

*** refers to compulsory answers**

FIRST PART (WELCOME PAGE AND QUESTIONS 1 TO 8)

Welcome page

La compilazione del questionario richiede da 10 a 15 minuti circa.

I dati raccolti saranno utilizzati esclusivamente per finalità di ricerca accademica al fine di analizzare il comportamento eco-innovativo delle imprese.

La ringraziamo in anticipo per il Suo contributo.

***Question no. 1 (Company size)**
Quanti dipendenti ha la sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)

Meno di 10	○
Tra 10 e 49	○
Tra 50 e 249	○
250 o più	○
Non so	○

***Question no. 2 (Company age)**
In che anno è stata fondata la Sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)

Prima del 1980	○
Tra il 1980 e il 1990	○
Tra il 1991 e il 2000	○
Tra il 2001 e il 2006	○
Tra il 2007 e il 2012	○
Dopo il 2012	○
Non so	○

Question no. 3 (Company's stage of development)
In quale stadio di sviluppo pensa si trovi la Sua impresa? (In caso di impresa multinazionale faccia riferimento all'affiliata italiana)
FASE SEED (l'idea imprenditoriale non ancora si è concretizzata nella realizzazione di un nuovo prodotto o servizio)
FASE DI START-UP (avvio dell'attività imprenditoriale con conseguente sviluppo e commercializzazione del prodotto o servizio)
FASE DI ESPANSIONE (l'impresa ha come obiettivo primario l'accrescimento del proprio business)
FASI SUCCESSIVE (l'impresa si prepara ad uscire dal mercato o a sostituire il capitale)
NON SO

***Question no. 4 (Drivers)**
Che importanza hanno avuto i seguenti fattori nella decisione della Sua impresa di operare nel settore del biogas? (1 = non importante ..... 4 = molto importante)

	1	2	3	4	Non so
Il rispetto delle normative ambientali	○	○	○	○	○
La domanda da parte dei Suoi clienti	○	○	○	○	○
La pressione esercitata da ambientalisti o gruppi di consumatori	○	○	○	○	○
La necessità di incrementare la competitività della Sua impresa	○	○	○	○	○
La domanda da parte dei Suoi fornitori	○	○	○	○	○
La pressione esercitata da parte di organizzazioni di categoria	○	○	○	○	○
La riduzione dei costi di produzione	○	○	○	○	○

Eventuali commenti (opzionale):

***Question no. 6 (Financial constraints)**
Nel reperire finanziamenti, quanto sono stati significativi i seguenti fattori nel limitare l'attività innovativa della Sua impresa? (1 = non significativo .... 4 = molto significativo)

	1	2	3	4	Non so
Potenziali investitori non sufficientemente esperti nel campo delle eco-innovazioni	○	○	○	○	○
Obiettivi dei potenziali investitori differenti da quelli della Sua impresa	○	○	○	○	○
Tipologie di finanziamento non adatte ai piccoli investimenti in eco-innovazioni	○	○	○	○	○
Ulteriori ostacoli esterni (opzionale)					
Eccessiva ingerenza nella gestione della Sua impresa da parte dei potenziali investitori	○	○	○	○	○
Mancanza di esperienza tecnica percepita dai potenziali investitori	○	○	○	○	○
Mancanza di esperienza imprenditoriale percepita dai potenziali investitori	○	○	○	○	○
Insufficienti garanzie disponibili	○	○	○	○	○
Limitatezza delle risorse dedicate alla ricerca dei finanziamenti	○	○	○	○	○
Scarsa conoscenza delle possibili opzioni di finanziamento	○	○	○	○	○
Ulteriori ostacoli (opzionale)					

***Question no. 7 (Environmental reputation)**
Ritiene che la reputazione ambientale della Sua impresa abbia influito sulla capacità di ottenere finanziamenti?

Sì ○
No ○
Non so ○

Eventuali commenti (opzionale):

***Question no. 8 (Easy access to funding eco-innovations)**
Ritiene sia più facile reperire finanziamenti per investimenti eco-innovativi piuttosto che per altri tipi di innovazioni?

Sì ○
No ○
Non so ○

SECOND PART (QUESTIONS 9 TO 10)

***Question no. 9 (Expectations)**
Quanto tempo ritiene sia ancora necessario perché si completi il passaggio all'utilizzo di solo biogas?

Meno di 10 anni ○
Tra 10 e 20 anni ○
Più di 20 anni ○
Non penso che il biogas riuscirà a sostituire definitivamente i carburanti tradizionali ○

***Question no. 10 (Knowledge)**
A quanti convegni, conferenze, tavole rotonde, ecc. con a tema il biogas ha preso parte (o ha organizzato) negli ultimi tre anni?

Nessuno ○
1-2 ○
3-4 ○
5 or more ○

THIRD PART (QUESTIONS 11 AND 12)

Per analizzare l'impatto dei vincoli finanziari nel settore del biogas, utilizzeremo una metodologia di ricerca definita 'Social Network Analysis' (SNA). La SNA consiste nel disegnare le reti di interazione tra gli attori operanti nel settore del biogas per poi verificare come tali reti sino eventualmente influenzate dall'esistenza di vincoli finanziari. Le elencheremo pertanto i nomi dei principali attori operanti nel settore del biogas chiedendoLe che tipo di interazione la Sua impresa ha avuto con loro negli ultimi tre anni ('Interazione Generica', 'Scambio di Conoscenze', 'Nessuna Interazione').

Si noti che:

- 'Interazione Generica' si riferisce a qualsiasi tipo di eventuali interazioni intercorse tra gli attori, non necessariamente legate alla produzione/utilizzo di biogas.
- 'Scambio di Conoscenze' si riferisce, invece, ad un eventuale scambio di conoscenze relativo alla produzione/utilizzo di biogas.

***Question no. 11 (Network design - Operators & Plant Suppliers)**
Che tipo di relazione ha avuto negli ultimi tre anni con i seguenti OPERATORI & FORNITORI DI IMPIANTI a biogas? (non tenga conto del rigo con il nome della Sua impresa)

	Solo Interazione Generica	Interazione Generica e Scambio di Conoscenze	Nessuna Interazione
1. Agraferm Italia	○	○	○
2. Austep	○	○	○
3. Bioconstruct Italia	○	○	○
4. Biogas Engineering	○	○	○
5. Bts Biogas	○	○	○
6. Corradi & Ghisolfi	○	○	○
7. Envitec Biogas Italia	○	○	○
8. Ies Biogas	○	○	○
9. Rota Guido	○	○	○
10. Schmack Biogas	○	○	○
11. Sebigas	○	○	○
12. Thöni	○	○	○
13. Uts Biogas	○	○	○
14. Com.It.E.A.	○	○	○
15. Wolf System	○	○	○
16. 4biogas	○	○	○
17. Planet Biogas Italia	○	○	○
18. Rwl Water Italia	○	○	○
19. Biogengas	○	○	○
20. Grimaldelli	○	○	○
21. Teta Project	○	○	○
22. Re-Energy Cooperativa Sociale	○	○	○
23. Trilogy Renewable Energy Pty	○	○	○
24. Eisenmann Italia	○	○	○
25. 2g Italia	○	○	○
26. Ab Energy	○	○	○
27. Schnell Motoren Ag	○	○	○
28. Agriplus	○	○	○
29. Eliopig	○	○	○
30. Eisenmann Italia	○	○	○
31. Siloxa Engineering Ag	○	○	○
32. Bilfinger Ems Gmbh	○	○	○
33. Gm Green Methane	○	○	○
34. Methapower Biogas Gmbh	○	○	○
35. Malmberg Water Ab	○	○	○
36. Air Liquide Italia Service	○	○	○
37. Sapio Energia	○	○	○
38. Siad Macchine Impianti	○	○	○
39. Microlng LLC	○	○	○
40. Hysytech	○	○	○
41. Geatech	○	○	○
42. Aqana BV	○	○	○
43. Pentair Haffmans Bw	○	○	○
44. Ges Global Environmental Solutions	○	○	○

***Question no. 12 (Network design – Institutional actors, Utilities, Universities)**
Che tipo di relazione ha avuto negli ultimi tre anni con i seguenti ATTORI ISTITUZIONALI/ASSOCIAZIONI/UNIVERSITA'?

	Solo Interazione Generica	Interazione Generica e Scambio di Conoscenze	Nessuna Interazione
45. CIB	○	○	○

46. Ministero dell'Ambiente	○	○	○
47. Ministero dello Sviluppo Economico	○	○	○
48. Confindustria	○	○	○
49. Agenzia AGIRE scarl	○	○	○
50. Agroenergia	○	○	○
51. BETA scarl	○	○	○
52. C.R.P.A. Centro Ricerche Produzioni Animali	○	○	○
53. PTP-Parco Tecnologico Padano	○	○	○
54. Veneto Agricoltura	○	○	○
55. C.I.C.A. BOLOGNA	○	○	○
56. Fondazione Edmund Mach	○	○	○
57. Confagriocoltura	○	○	○
58. AIFE - Associazione Italiana Foraggi Essicati	○	○	○
59. Kyoto Club	○	○	○

FOURTH PART (QUESTION 13 AND CONCLUSIONS)

***Question no. 13 (Identification)**
Nome dell'impresa

Il Suo nome

Il Suo cognome

La Sua posizione lavorativa (il Suo ruolo) all'interno dell'impresa

Final comments
Eventuali osservazioni o commenti (opzionale):

La ringrazio per il tempo che ha dedicato alla compilazione del questionario.

La Sua collaborazione è stata preziosa!